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Understanding the usability of an mHealth tool to support medication adherence schedules in newly diagnosed tuberculosis patients: A mixed-methods research study

by

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DECLARATION

I, **Tebogo Sole Moloto,** hereby declare that:

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Date: **August 2024**

ABSTRACT

Tuberculosis is an infectious disease, one which is curable and preventable. Alongside HIV, TB ranks as a leading cause of death worldwide. Although TB monitoring using direct observation of therapy has seen remarkable success in specific contexts, it still has limitations related to improving adherence. The use of technology-driven supportive tools aimed at increasing ongoing adherence has the potential to improve medication adherence. However, evidence remains minimal. The main purpose of this study was to determine the influence of mobile health (mHealth), for example through wisepill technology feedback reminders, on newly diagnosed TB patients' adherence to medication. The study intended to demonstrate medication adherence by using TB patients' perceptions of self-efficacy and stigma to predict successful treatment outcomes, and to understand, through TB patient experiences, the barriers to adoption and sustainable use of mHealth technologies. A mixed-methods research design using purposive and convenience sampling was utilised to acquire understanding of the usability of an mHealth tool to support medication adherence schedules in tuberculosis patients. The sample comprised 90 patients with drug-susceptible tuberculosis. Quantitative results revealed that supportive feedback reminders from wisepill technology did not increase adherence over time. Adherence scores from wisepill differed significantly from patients' subjective reports on adherence. Wisepill technology, stigma and self-efficacy predicted successful treatment outcomes, once reminders from wisepill technology were added. A sample of 10 participants were interviewed. Thematic analysis of the qualitative data established four themes, namely: 1) end-user experiences; 2) the influence of using the mHealth tool during TB treatment; 3) stigma and self-efficacy; and 4) sustainability of using the mHealth tool. Key lessons acquired from the qualitative findings highlighted that feedback reminders encouraged medication intake, it is valuable and provides companionship in supporting the participants' treatment journey. The qualitative results enhanced the quantitative results and created a sense of convergence. The study generated evidence-based knowledge of mHealth use and adherence over time in a South African context. Usability of adherence technologies, coupled with improved adherence and treatment outcomes, can inform policymakers in defining the national standard for TB adherence to reduce transmission of the disease. In addition, this understanding is of key importance for developing intervention programmes to improve medication adherence among TB patients.

Keywords: Medication adherence, mobile health (mHealth), self-efficacy, stigma, tuberculosis (TB), and wisepill technology

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LIST OF ACRONYMS AND ABBREVIATIONS

Abbreviation	Definition
ART	Antiretroviral Therapy
BMQ	Brief Medication Questionnaire
CHC	Community Healthcare
CMG	Cumulative Medication Gap
DAT	Digital Adherence Technologies
DOH	Department of Health
DOT	Directly Observed Therapy
DR-TB	Drug-resistant Tuberculosis
DS-TB	Drug-susceptible Tuberculosis
eHEALTH	Electronic Health
EMD	Electronic monitoring devices
HCP	Healthcare providers
HBM	Health belief model
HIS	Health Information System
HIV	Human immunodeficiency virus
HPCSA	Health Professions Council of South Africa
INH	Isoniazid
IT	Information Technology
LMICs	Low- and Middle-income Countries
MARS	Medication Adherence Rating Scale
MASES-R	Medication Adherence Self-efficacy Scale Revised
MEMS	Medication Event Monitoring System
mHEALTH	Mobile Health
MMAS	Morisky Medication Adherence Scale
MDR-TB	Multi-drug-resistant Tuberculosis
MPR	Medication Possession Ratio
MTB	Mycobacterium Tuberculosis

Abbreviation	Definition
PDAs	Personal Digital Assistants
PLWHIV	People Living with HIV
PDC	Proportion of Days Covered
PTB	Pulmonary Tuberculosis
REDCap	Research Electronic Data Capture
SA	South Africa(n)
SAT	Self-administeredTtreatment
SCT	Social Cognitive Theory
SMS	Short Message Service
SCV	Statistical Conclusion Validity
SSCI-8	Stigma Scale for Chronic Illnesses 8-item version
TSR	Treatment Success Rate
TB	Tuberculosis
TB DIAH	TB Data Impact Assessment and Communications Hub
UHC	Universal Health Coverage
UP	University of Pretoria
VL	Viral Load
WHO	World Health Organization
WOT	Wirelessly Observed Therapy
XDR-TB	Extensively Drug-resistant Tuberculosis

CHAPTER 1: INTRODUCTION

This chapter provides an overview of the study, which includes the background, statement of the research problem, research question and hypotheses. The aim and objectives are also outlined, and followed by a section dedicated to the significance of the study. The theoretical framework used to guide the study, along with the methodology applied, is also briefly outlined.

1.1 BACKGROUND, MOTIVATION AND RATIONALE OF THE STUDY

Tuberculosis is an infectious disease caused by the bacillus *mycobacterium tuberculosis*, affecting the lungs (pulmonary TB) and other sites of the organs (extrapulmonary). Although the disease is curable and preventable, alongside the human immunodeficiency virus (HIV), TB ranks as a leading cause of death worldwide. Extant literature suggests that the high prevalence of TB continues to be a leading cause of death owing to insufficient treatment which is partly ascribable to non-adherence. Medication non-adherence is one of the most significant obstacles to TB control globally (Kvarnström et al., 2021). The key drivers of non-adherence include the biological (i.e. HIV co-infection, diabetes), economic (i.e. lack of money and transport), personal (i.e. fear of disclosure, misinformation about the disease's transmission and stigma) and social factors (i.e., poverty, substance use, undernutrition and overcrowding) (Marahatta et al., 2020; Nezenega et al., 2020). In 2020, TB was responsible for 1.5 million deaths worldwide (World Health Organization [WHO], 2021), with South Africa ranking among the countries with the highest TB burden. The country is plagued by poverty, extreme income inequality and high levels of unemployment – this further exacerbates the breeding ground for TB to flourish because it is prototypically understood as a disease of poverty (Nature Communications, 2024). To combat TB and ensure effective treatment, the World Health Organization's (WHO) End TB Strategy has employed direct observed therapy (DOT) as a standard for monitoring TB medication adherence. While DOT has seen remarkable success in specific contexts, it still has limitations relating to improving adherence (DiStefano & Schmidt, 2016).

Lack of adherence to TB medication is an important driver for transmission, emergence of drug resistance, relapse, and death (Gashu et al., 2021; Gebreweld et al., 2018; Sahile et al., 2018). If TB is not managed, the following outcomes may be the result:

- Increases in the number of people with TB who are not detected by health services will result in increases in the number of people with undiagnosed and untreated TB in the community.
- Increases in transmission of TB infection will, in turn, with a time lag, have the result of increasing the number of people who go on to develop TB.

- Economic impact is predicted to worsen livelihoods resulting from lost income or unemployment – this could also increase the percentage of people with TB and their households facing catastrophic costs (WHO, 2020).
- Increase in the global burden of TB disease.

Currently, there is no "gold standard" to measure TB treatment adherence. Two different methods are recommended to measure TB treatment adherence: 1) objective methods (DOT and detection of drug and metabolites concentration in urine – which are usually more expensive and invasive, although they provide solid proof of the ingestion of medication); and 2) subjective measures (patient self-reports, pill count, electronic monitoring and text messaging – which are easy to implement and inexpensive, but lack reliability and accuracy) (Anghel et al., 2019). Although adherence measured by subjective methods are considered unreliable (Thamineni et al., 2022), combining them results in effective interventions used to assess and improve medication adherence in TB patients (Pradipta et al., 2020).

Implementing tools and strategies to improve adherence is crucial. A technology-driven, supportive tool is an option that can be used to increase adherence (Chun Yun Kang 2022; Kleinsinger, 2018). However, promoting treatment adherence among TB patients remains underfunded (Frick & Lessem, 2018; Mussie, 2023). The support provided by mobile health (mHealth) technologies has the potential to improve medication adherence if deviations (when a patient skips taking medication) are detected (Aldeer et al., 2018; Arshed et al., 2023; Ngwatu et al., 2018). Mobile health technologies therefore have the potential to encourage patients to become active agents in managing their health and treatment.

An example of a mobile health tool currently used with several disorders is the evriMED wisepill box – it is an automated electronic device that records and informs the healthcare provider of the regularity with which a medicine container is opened by the patient (assuming that in most cases when the device is opened medication is taken). Information from the device is used as proxy and sent to a remote web-based server. A reminder text message is sent both to the patient and to the research assistant(s) whenever the device has not been opened within the prescribed time window. A detailed infographic overview of the wisepill procedures is available in Appendix 1 (Karumbi & Garner, 2015).

Technology-driven mobile health interventions are flexible, cost-effective, and have the capacity to reach across geographic locations, including resource-limited settings (Hasker et al., 2010). Current evidence proposes that the focus is on understanding the connection between patient experience, adherence, and health outcomes (Hamine et al., 2015), as these technologies have not yet been fully explored and there are variations in assessing their quality (Agarwal et al., 2021; Muessig

et al., 2017). Furthermore, there is limited data on the correlation of mHealth features and statistically significant outcomes (Donevant et al., 2018) The impact of applied mHealth and the perceived quality of care delivery has not been explored in depth (Kutney-Lee et al., 2019; O'Connor et al., 2020).

In this study, data collected on the usability of an mHealth tool (the wisepill box device) to support medication adherence schedules in newly diagnosed tuberculosis patients was explored. The patients were receiving TB treatment at five of the six clinic facilities in Ekurhuleni, South Africa. This study is one of many pilot projects currently being conducted in various countries to understand how technology-driven mHealth can contribute to the alleviation of TB by encouraging medication adherence. This initiative is in line with the WHO's strategy plan to end the global TB epidemic.

1.2 RESEARCH PROBLEM AND QUESTION

Potential barriers to appropriate medication adherence include self-efficacy and experiencing stigma (Adefolalu et al., 2014; Huang et al., 2013; Náfrádi et al., 2017). Patients' illness perceptions and health beliefs may also reduce their motivation to adhere to treatment (Easthall & Barnett, 2017). Tuberculosis treatment and management is based on patients' ability to take their medication as prescribed by the healthcare provider. This requires patients to believe in their ability to follow instructions and to implement behavioural changes in accordance with medical advice (Nwagu et al., 2020). Patients' personal theories of how they think others perceive the TB disease and treatment may derive from the stigma associated with the disease, which may also compromise their adherence behaviour. Improving adherence requires an active process of behavioural change, education, motivation, tools, support, monitoring and evaluation (Kini & Ho, 2018; Kleinsinger, 2018; Nieuwlaat et al., 2014: Read et al., 2020). A valuable tool that can be used to improve adherence is mHealth (Ni et al., 2018; Park et al., 2020).

Self-efficacy refers to the individual's personal beliefs regarding their capabilities to carry out a specific task to achieve a desired outcome (Bandura, 1989). It is one of the cognitive variables that has an influence on people's behaviour and is a determining factor in health behaviour change and maintenance (Martos-Méndez, 2015). Self-efficacy is related to adherence. For example, when a patient perceives themself as being able to take the medication as prescribed, it is an encouragement to adhere to treatment. Self-efficacy is a key driver of a positive attitude to treatment compliance (Okuboyejo et al., 2018). Understanding the role of self-efficacy is critical to ascertain patients' confidence in their medication adherence (Rosli et al., 2022). It is therefore important to explore self-efficacy in the context of TB, especially given the South African context and issues relating to limited education. Another highlighted major obstacle in treatment adherence is stigma, which is, in part, attributed to patients' illness cognitions (personal theories that may be inaccurate, or based on cultural

factors, education, and other social factors). Stigma is frequently described as a process of devaluation, whereby stigmatised people are discredited, seen as a disgrace, perceived to have less value or worth, or even seen as a danger. Therefore, TB stigma has been attributed to policies that designate TB patients as a public health threat (Daftary, 2018), the rise in drug-resistant TB strains, TB linked to low socioeconomic position (Agodi, 2015), knowledge of TB/HIV duality (DeSanto et al., 2023), and cultural myths (i.e., curses or associations with supernatural forces like witchcraft) (Matakanye et al., 2021). Stigma influences treatment. Tuberculosis-related stigma is a persisting issue because people exaggerate the contagiousness and fear of infection (Duko et al., 2019). In addition, lack of understanding contributes to people's false perceptions that TB is incurable and is highly contagious throughout treatment (Chang & Cataldo, 2014). For example, patients who feel stigmatised by their suffering from the TB illness avoid taking medication and this can hinder adherence (DiStefano & Schmidt, 2016; Kvarnström et al., 2021). Furthermore, these individuals may less frequently use health services and may conceal their illness because of low self-esteem and social isolation (Chen et al., 2021). Thus, both self-efficacy and stigma are important main variables of the study and have an impact on medication adherence in general and, more specifically, in the context of TB. The choice to investigate stigma and self-efficacy in particular is due to their translational link to behaviour and subsequent health outcomes. For example, experiencing high stigma has been negatively associated with self-efficacy (Luthuli & John-Langba, 2024). This can affect the patients' confidence to adhere to treatment and lead to further unfavourable treatment outcomes.

There is a need to investigate the behavioural change component emanating from mHealth use (Petit & Cambon, 2016) by measuring the influence of mHealth use on patients' motivation to complete treatment, given their perception of stigma and self-efficacy. Perceptions of a chronic illness are important because they reflect the patients' role in exercising personal agency to improve their health outcome (Adams, 2010; Hibbard & Greene, 2013). In addition, research needs to investigate end-user experiences to understand barriers to adoption and the sustainability of mHealth technologies (integration of technology with everyday life in the context of already established disease self-management routines).

The researcher formulated the following research questions:

Primary research question: To what extent did mHealth feedback reminders influence TB patients' medication adherence behaviour (given their perceptions of stigma and self-efficacy)?

Secondary research question: How did TB patients experience the use of mHealth feedback reminders and what barriers did they experience in using the mHealth technology?

1.3 AIMS AND OBJECTIVES OF THE STUDY

The main aim of this study was to determine the influence of mHealth feedback reminders on TB patients' medication adherence. The TB patients' perceptions of self-efficacy and stigma were measured to predict successful treatment outcomes to signify medication adherence. In addition, a secondary aim intended to understand, through TB patient experiences, the barriers to adoption and sustainable use of mHealth technologies – this is the focus of the study's qualitative component. To achieve the above-mentioned aims, the following objectives guided this study:

- To measure medication adherence and feedback reminders using wisepill technology.
- To measure medication adherence from patient self-reports and a three-item adherence scale.
- To compare scores from wisepill technology with other subjective scores (completed medication in each month, missed doses in each month and a three-item adherence scale).
- To measure the predictive ability of adherence scores from wisepill technology on TB treatment outcomes.
- To measure the predictive ability of stigma and self-efficacy on TB treatment outcomes even when reminders from wisepill technology are added.
- To explore the TB patients' experiences with mHealth technology.
- Psychological issues relating to medication adherence and feedback reminders from the mHealth technology were measured quantitatively, while the TB patients' experiences of the mHealth technology was explored qualitatively.

1.4 RESEARCH HYPOTHESES

The researcher tested the following research hypotheses and dealt with a qualitative research question to determine the usability of an mHealth tool supporting medication adherence schedules in newly diagnosed tuberculosis patients:

- **Quantitative hypotheses:-**

  Hypothesis 1: On supportive feedback (reminders) from wisepill technology and adherence over time.

  H_1: Supportive feedback (reminders) from a wisepill technology will increase adherence over time.

  H_0: Supportive feedback (reminders) from a wisepill technology will not increase adherence over time.

Hypothesis 2: Wisepill technology scores versus subjective scores

H_1: Wisepill technology scores and other subjective scores (completed medication in each month, missed doses in each month and a three-item adherence scale) will differ.

H_0: Wisepill technology scores and other subjective scores (completed medication in each month, missed doses in each month and a three-item adherence scale) will not differ.

Hypothesis 3: Adherence scores from wisepill technology is a predictor for TB treatment outcomes.

H_1: Adherence scores from wisepill technology will predict TB treatment outcomes.

H_0: Adherence scores from wisepill technology will not predict TB treatment outcomes.

Hypothesis 4: Stigma and self-efficacy as predictors of adherent behaviour

H_1: Stigma and self-efficacy will predict adherence behaviour (TB medication adherence) even if reminders from wisepill technology are added.

H_0: Stigma and self-efficacy will not predict adherence behaviour (TB medication adherence) even if reminders from wisepill technology are added.

1.5 SIGNIFICANCE OF THE STUDY

Declining trends in quality healthcare have caused the public to lose trust in the healthcare system in South Africa (Maphumulo & Bhengu, 2019). South Africa is characterised by social inequality, poverty, unemployment, low education levels, high burden of diseases and the inequitable quality of healthcare service provision (de Villiers, 2021). Although the country's health system is presently engaged in a process of establishing universal health coverage that will enable the system's ability to deliver comprehensive care that is accessible, affordable, and acceptable to patients and families (de Villiers, 2021), further improvements are nevertheless required. This year in May, President Cyril Ramaphosa signed the National Health Insurance (NHI) Bill into law. This is a crucial step to highlight the government's commitment to a healthcare system that serves all South Africans. Therefore, the value of this research is to demonstrate how mHealth technology can help to alleviate some of these issues and ultimately the burden on the healthcare system in terms of cost. Digital technologies demonstrate the capacity for innovation required in health and could resolve some issues of health equity such as acceptability and sustainability (Stoumpos et al., 2023).

The results generated from this study may contribute to more evidence-based knowledge of mHealth use and medication adherence over time. Research results furthermore envisage contributing to the improvement of medication adherence and overall TB treatment outcomes, specifically in the South African context. Patients using mobile technology to understand medication adherence in a

chronic disease (TB) makes an important contribution to science, because it reflects their role in exercising personal agency to improve their health outcomes. It is evident from the literature (Adefolalu et al., 2014; Burtscher et al., 2016; Craig et al., 2017; de Almeida Crispim et al., 2017; DiStefano & Schmidt, 2016; Huang et al., 2013; Kamaradova et al., 2016; Kvarnström et al., 2021; Marahatta et al., 2020; Mhode & Nyamhanga, 2016; Náfrádi et al., 2017; Nezenega et al., 2020) that psychological issues such as lack of self-efficacy and stigma represent barriers to TB adherence. However, the need exists to apply context-specific self-efficacy measures for predicting medication adherence and increasing the use of validated instruments to quantify the impact of stigma on treatment compliance. This study therefore focused on the patient's perception of the illness (self-efficacy and stigma) considering understanding the barriers to adoption and sustainability of using the mHealth technology from the TB patient's perspective.

The novelty of the study is using alternative and innovative approaches to improve adherence to TB therapy because it is critical for the success of TB treatment. The long duration of anti-TB treatment poses significant challenges to TB patients, especially non-adherence to medication. Therefore, evidence generated on the application of a patient-centred approach to improve adherence and treatment outcomes can be used by policymakers in defining the national standard for TB adherence. This will have a strong public health impact in reducing transmission of the disease, informing the development of the treatment cascade from testing to treatment completion and cure.

1.6 CONCEPTUAL FRAMEWORK: SOCIAL COGNITIVE THEORY

The guiding conceptual framework followed in this study was the social cognitive theory. This theory is based on assumptions that expectations, thoughts, and beliefs influence an individual's behaviour and that they are shaped by the individual's social environment (Bandura, 1986). According to Islam et al. (2023), Bandura's SCT is useful for studies focused on behaviour change in health promotion research. Furthermore, SCT-based interventions positively impact health outcomes and intervention effectiveness (Islam et al., 2023). From the perspective of SCT, the researcher focused on the health belief model (HBM) to understand the phenomenon of adherence. The model explains change in and maintenance of health-related behaviours with the use of supportive interventions designed to change health behaviour (Champion et al., 2019). In the context of this study, the wisepill device is an adherence measurement tool used to explain TB patients' medication use. The wisepill device indirectly reflects TB patients' medication adherence behaviour and their motivation to complete treatment. By virtue of monitoring, patients are influenced by the device to adhere to timely medication use, and their motivation to adhere may translate into behavioural change (medication adherence).

1.7 METHODOLOGY

A "mixed methods research approach combining qualitative and quantitative methods throughout the research process" was used in this study (Creswell, 2015, p. 18; Creswell & Creswell, 2017). A sequential explanatory design was employed that prioritises both methods equally. In such a design, collection and analysis of two independent strands of quantitative and qualitative data take place sequentially, at different points in time – a quantitative phase followed by a qualitative phase. The results were then collated. Quantitative data collected comprised adherence information obtained using the following instruments:

- Wisepill technology;
- Patient self-reporting;
- Pill counts;
- Three-item adherence scale (Fowler et al., 2016; Gaito, 1980; Townsend et al., 1984; Wilson et al., 2014; Wilson et al., 2016);
- Self-efficacy was measured using the medication adherence self-efficacy scale revised (MASES-R) (Fernandez et al., 2008);
- Stigma was assessed using the stigma scale for chronic illnesses 8-item version (SSCI-8) (Molina et al., 2013).

A sociodemographic questionnaire was also administered to obtain descriptive information (household characteristics, education level and employment status). Details about the diagnosis date, treatment start date and overall TB outcomes were obtained from the patient files – access was provided by the facility-registered nurse who also assisted with the recruitment of participants.

Qualitative data were collected through semi-structured interviews with a small sample of 10 study participants who used the evriMED wisepill box to support their medication adherence. Convenience sampling was employed. The study integrated quantitative and qualitative data through joint displays – which provided a structure for the results (Guetterman et al., 2015). Comparisons were made between experiences of patients with high and low adherence to understand how the reminders may have or may not have affected their behaviour. The analysis highlighted convergence and divergence from this combination as quantitative and qualitative results have equal weight.

1.8 DIVISION OF CHAPTERS AND LAYOUT OF THE THESIS

- **Chapter 1: Introduction**

The introduction comprises the background of the study, statement of the research problem, purpose and significance of the study, research hypotheses and questions, and overview of the research design.

- **Chapter 2: Literature Review**

In this chapter, the literature is reviewed on the TB context, medication adherence, methods used to measure TB treatment adherence, digital adherence technologies (DAT), including mHealth tools and ethical issues posed by DATs. Literature illustrates that more evidence-based knowledge of mHealth use and adherence over time (specifically in the South African context) could prevent new infections of mycobacterium tuberculosis (MTB), progression to tuberculosis (TB) disease and eventually achieve the End TB Strategy targets set for 2030 and 2035.

- **Chapter 3: Theoretical Framework and Paradigmatic Point of Departure**

The researcher describes the theoretical approach and the paradigmatic point of departure for the study in this chapter. The health belief model was used to understand the phenomenon of adherence. This concept derives from the social cognitive theory, which emphasises how behavioural, personal and environment factors play a role in human behaviour.

- **Chapter 4: Research Methodology**

In this chapter, the researcher discusses the methodology that was employed and the procedures that were followed to answer the research questions and to ensure that the study was conducted in an ethical manner. The focus was on maintaining the validity, trustworthiness, and quality of the research.

- **Chapter 5: Findings**

The results of the quantitative and qualitative data analyses are presented in this chapter.

- **Chapter 6: Discussion**

In this chapter, the findings are integrated and discussed using joint displays. The researcher outlined the implications of the study findings for theory and practice and made recommendations for future research. The recommendations relate to the usability and sustainability of using mHealth tools to support medication adherence. The conclusions of this study are grounded in relevant literature and acknowledge the shortcomings and other limitations of the study.

1.9 CONCLUSION

The primary aim of this study was to determine the influence of mHealth feedback reminders on TB patients' medication adherence and to understand, through TB patients' experiences, the barriers to adoption and sustainability of mHealth technologies. The problem statement was detailed, along with the research questions, aims and objectives. This chapter also briefly presented a sequential overview of the dissertation chapters to follow. Extant literature related to the subject matter is highlighted in the next chapter.

CHAPTER 2: LITERATURE REVIEW

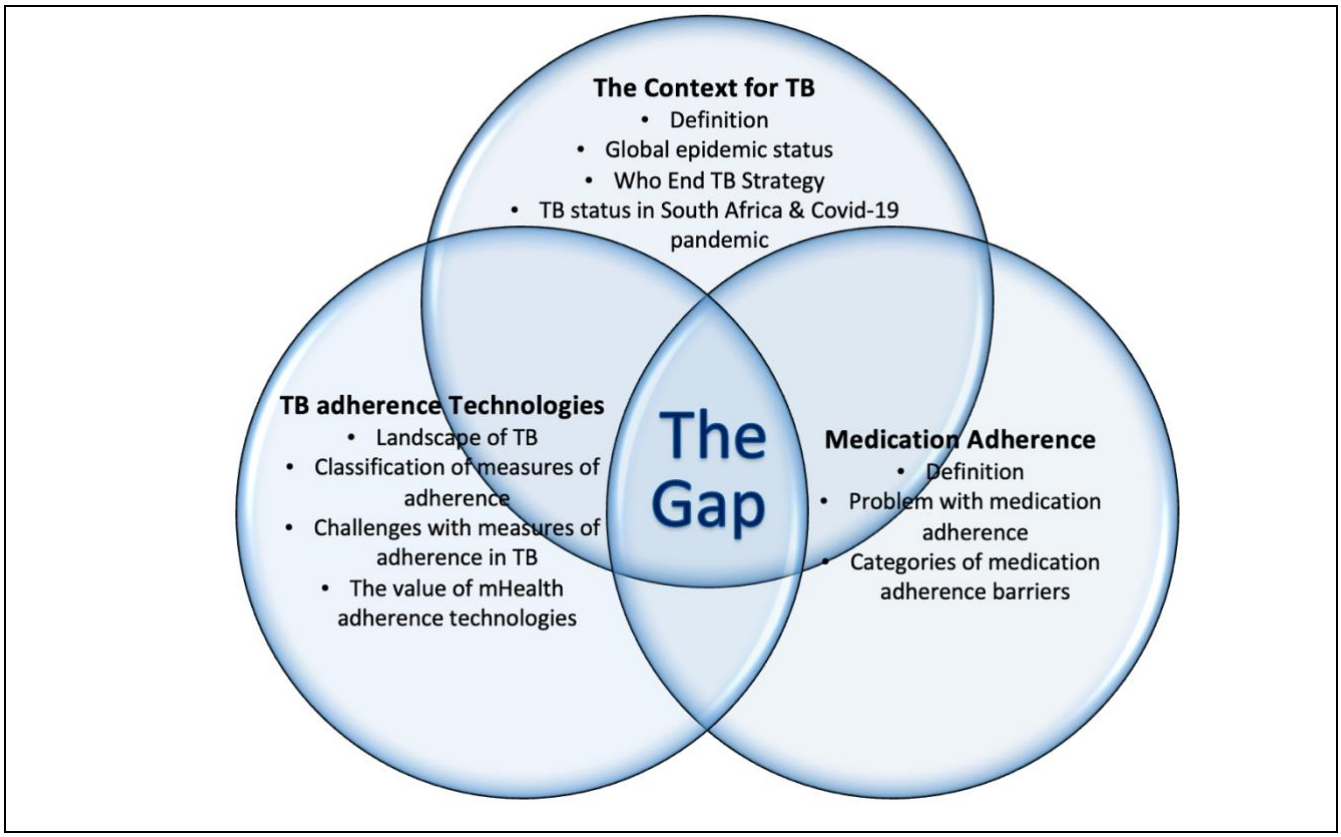
The focus of the literature review is on the landscape of digital adherence technology to support the healthcare system and medication adherence in tuberculosis patients. A Venn diagram (Figure 2.1) illustrates the organisation of the literature review. In this literature review, TB is defined in the context of burden of disease, while the global and local status of the epidemic is highlighted, the progress towards the End TB Strategy is reported, and the impact of the Covid-19 pandemic on TB treatment goals are discussed. Medication adherence, the issue of non-adherence, and factors or barriers associated with medication adherence is also outlined. A section dedicated to the classification of methods used to measure TB adherence, the value of mHealth adherence technologies and current research gaps are included.

2.1 DIAGRAMMATIC ILLUSTRATION OF THE LITERATURE REVIEW

A Venn diagram was used to represent a visual image that demonstrated existing research on TB and the treatment adherence referred to in this chapter. Figure 1 is a visual presentation of how this chapter is structured.

Figure 1:

Description of Relevant Literature Topics for this Study



2.2 CONTEXT OF TUBERCULOSIS

Tuberculosis is an infectious disease that is curable and preventable. Tuberculosis ranks as a leading cause of death worldwide. In 2020 TB was responsible for 1.5 million deaths worldwide (WHO, 2021). Tuberculosis is manageable and curable if people take their medication as prescribed. Medication adherence continues to be an important challenge in healthcare, with a shortage of effective interventions to address this matter. Although DOT as a standard for monitoring TB medication has seen remarkable success in specific contexts, it has shown limitations in respect of improving adherence. Therefore, the need to develop technology-driven supportive tools aimed at increasing ongoing adherence is critical. Mobile health technologies have the potential to improve medication adherence, although evidence remains minimal (Kleinsinger, 2018).

The treatment success rate of 80% to 90% defined in the study is guided by the WHO's expected TSR of 90% for all countries (Stop TB Partnership, 2017), the TB data, impact assessment and communications hub (TB DIAH) project (the website features a data hub, guidance, and tools to support the work of the global TB community). TB DIAH enables optimal analysis and use of TB data to inform national TB programmes, policies, and USAID-supported interventions. The latest figure shown on the USAID dashboard for 2020 reported 78.97% of the TB treatment success rate in South Africa (TB DIAH, 2024). In addition, a study conducted by Berry et al. (2019) on TB treatment outcomes across ages children to older adults) in the metropolitan municipalities of Ekurhuleni Metropolitan Municipality and the City of Johannesburg found that successful treatment exceeded 80% (i.e. 83.48%) in all age groups (Berry et al., 2019). Although the treatment success is high, the country still falls short of the standard set by WHO.

In addition to the background of the study, the definition of TB as well as the global and local epidemic status of TB is discussed below.

2.2.1 Definition of Tuberculosis

Tuberculosis is an infectious disease that is caused by a type of bacteria known as *mycobacterium tuberculosis*. The disease most often affects the lungs (pulmonary TB) and other sites of the organs (extrapulmonary). It spreads through the air when infected individuals cough, sneeze or spit. Tuberculosis is curable and preventable, although it persists in being the leading cause of death alongside HIV (WHO, 2020). It is estimated that a quarter of the world's population is infected with TB. However, most of these people have latent TB (the TB bacteria lives in the body without causing illness). TB can affect anyone, anywhere, but most people who develop the disease are adults, with more cases among men (aged ≥15 years), who accounted for 57% of all TB cases in 2018, compared

to women, who accounted for 32% (WHO, 2020). There are 30 high-TB burden countries in the world, which account for almost 90% of people who fall ill with TB each year. South Africa ranks among the countries with the highest TB burden. In 2019, about 360,000 South African people fell ill with TB and 58,000 died from the disease (WHO, 2020). People affected with TB are often faced with poverty, economic distress, vulnerability, marginalisation, stigma, and discrimination, which are risk factors for TB (WHO, 2020). In essence, if an individual has TB, they are very likely to be experiencing some of these challenges.

Although TB services are free in South Africa, issues of income loss and costs incurred by patients on food, nutrition and travel persists. Therefore, the WHO has supported a multisectoral accountability framework for TB developed by the Department of Health in 2022. This framework entails bringing together different actors from government departments, civil society and the private sector under the coordination of the South African National AIDS Council (SANAC). The aim is to address the social determinants of TB and contribute to the TB response (WHO South Africa, 2024).

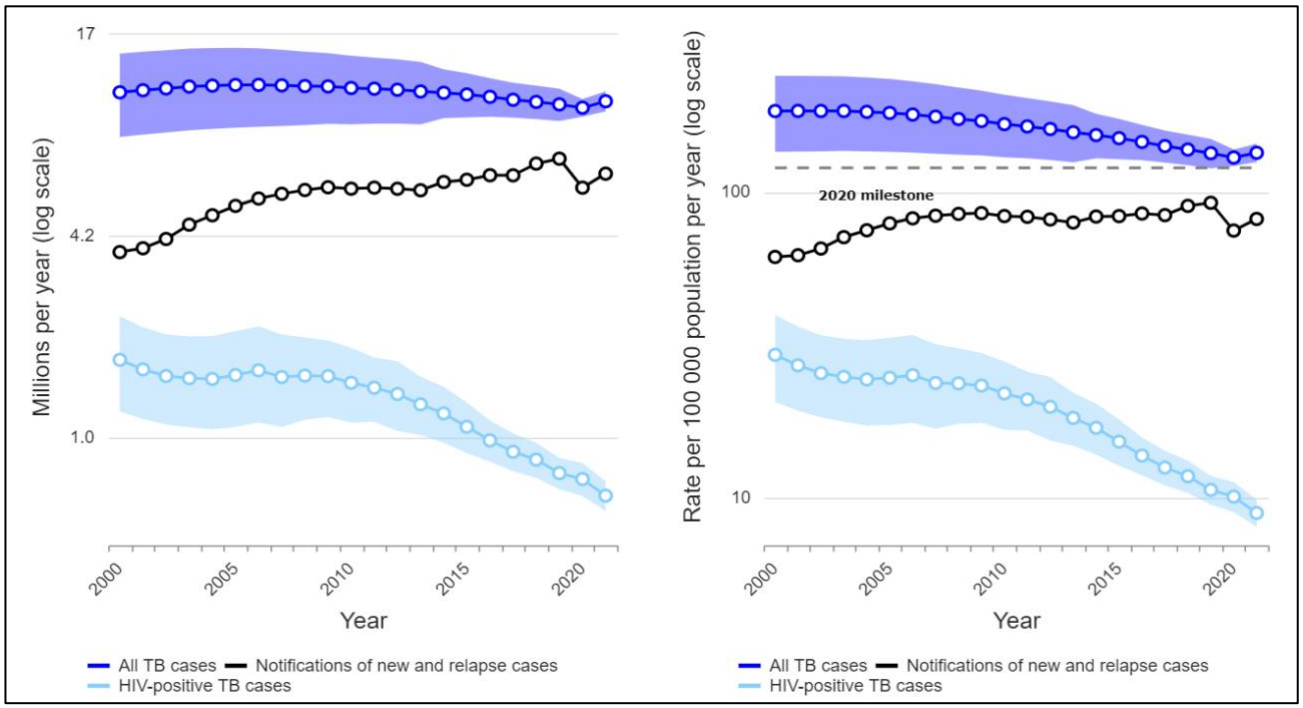
Preventive treatment is available for people with TB infection. About 85% of people who develop TB disease can be treated successfully with a 6-month treatment plan, which has the additional benefit of decreasing transmission of infection. Since 2000, it is estimated that TB treatment has prevented more than 60 million deaths, although access to universal health coverage (UHC) still falls short. Furthermore, many millions also lacked diagnosis and care (WHO, 2020).

2.2.2 Global Tuberculosis Epidemic Status

Globally, an estimated 10.6 million ranging from 9.9 to 11.1 million, new TB cases were identified in 2021 compared to 10.2 million, ranging from 9.5 to 10.7, in 2020. This means there is a reversal of progress compared to years of slow decline trends (see Figure 2). Similarly, the TB incidence rate, namely new cases per 100 000 population per year, is estimated to have increased by 3.6% between 2020 and 2021, following declines of about 2% per year for most of the past two decades (see Figure 2) (WHO, 2022).

Figure 2:

Global Trends in the Estimated Number of Incident TB Cases (left) and Incidence Rate (right), 2000–2021



Source: The image was obtained from *Global tuberculosis report 2022,* (p.13), by the World Health Organization, 2022, (https://www.who.int/teams/global-tuberculosis-programme/tb reports/global-tuberculosis-report-2022).

2.2.3 World Health Organization's End Tuberculosis Strategy

The WHO adopted the End TB Strategy after 2015 and aims to end the global TB epidemic as part of the newly adopted Sustainable Development Goals. Furthermore, the strategy proposes to end the global TB epidemic by 2035. The strategy targets a 90% reduction in patients suffering from TB, a 95% reduction in deaths from TB by 2035, and the protection of families from catastrophic costs that push them even further into poverty. The strategy involves a set of targets that are measured through milestones by using the three indicators seen in Figure 2. In this case, the strategy included milestones (for 2020 and 2025) and targets (for 2030 and 2035) for large reductions in the TB incidence rate (new cases per 100 000 population per year), the absolute number of deaths caused by TB, and costs faced by TB patients and their households (see Figure 3). To reach these milestones and targets, an annual decline in the TB incidence rate of 4% to 5% per year by 2020, accelerating to 10% per year by 2025 and then to an average of 17% per year from 2025 to 2035 is required (WHO, 2023).

The framework captures the diversity of TB epidemiology in the region, ranging from low-burden countries that are on the verge of eliminating TB, to countries with a very high-TB burden. Key requirements to reach the milestones and targets are defined in the three pillars of the End TB Strategy, namely: 1) provision of TB prevention, diagnostic and treatment services in the context of progress towards UHC and social protection; 2) multisectoral actions to address broader social and economic

determinants of TB; and 3) technological breakthroughs, such as a new TB vaccine by 2025. South Africa has prioritised vaccine preparedness as reflected in the National TB Programme (NTP) Strategic Plan, 2023-28. In collaboration with the national TB Think Tank and the National Advisory Group on Immunisation (NAGI), preparatory work for the introduction of TB vaccines is currently in progress. The WHO (2023) provides technical support to member states in adapting and implementing the regional framework. Furthermore, support includes revisiting challenges and actions in four layers: TB-specific challenges; challenges in health systems that influence TB care; challenges in sectors beyond health that determine TB; and overarching governance issues (WHO, 2023).

In relation to the above, this study links up with pillars one and three. The first pillar deals with integrated, patient-centred care and prevention. The component of interest is the treatment of all people with TB and providing patient support. The third pillar highlights research and innovation. The study is focused on the uptake of new tools as part of the intervention and the implementation of innovative technologies to measure their impact. This research study can contribute to reaching the goal of ending the global TB epidemic by supporting patients on TB treatment in their adherence to medication regimes using mHealth technology. The implementation of this innovative support technology is highly relevant for informing the health system on the impact it makes by generating scientific evidence. In addition, this study also explores the possibilities of making the mHealth tool available and accessible to patients in a wider South African context.

Figure 3:

Summary of the Global End TB Strategy

Box 2. The End TB Strategy at a glance

VISION	A WORLD FREE OF TB — zero deaths, disease and suffering due to TB			
GOAL	END THE GLOBAL TB EPIDEMIC			
INDICATORS	MILESTONES		TARGETS	
	2020	2025	2030	2035
Percentage reduction in the absolute number of TB deaths[a] (compared with 2015 baseline)	35%	75%	90%	95%
Percentage reduction in the TB incidence rate (compared with 2015 baseline)	20%	50%	80%	90%
Percentage of TB-affected households facing catastrophic total costs due to TB[b] (level in 2015 unknown)	0%	0%	0%	0%

PRINCIPLES

1. Government stewardship and accountability, with monitoring and evaluation
2. Strong coalition with civil society organizations and communities
3. Protection and promotion of human rights, ethics and equity
4. Adaptation of the strategy and targets at country level, with global collaboration

PILLARS AND COMPONENTS

1. INTEGRATED, PATIENT-CENTRED CARE AND PREVENTION

A. Early diagnosis of TB including universal drug-susceptibility testing, and systematic screening of contacts and high-risk groups
B. Treatment of all people with TB including drug-resistant TB, and patient support
C. Collaborative TB/HIV activities, and management of comorbidities
D. Preventive treatment of persons at high risk, and vaccination against TB

2. BOLD POLICIES AND SUPPORTIVE SYSTEMS

E. Political commitment with adequate resources for TB care and prevention
F. Engagement of communities, civil society organizations, and public and private care providers
G. Universal health coverage policy, and regulatory frameworks for case notification, vital registration, quality and rational use of medicines, and infection control
H. Social protection, poverty alleviation and actions on other determinants of TB

3. INTENSIFIED RESEARCH AND INNOVATION

I. Discovery, development and rapid uptake of new tools, interventions and strategies
J. Research to optimize implementation and impact, and promote innovations

a. This indicator is for the combined total of TB deaths in HIV-negative and HIV-positive people. Deaths from TB among HIV-positive people are officialy classified as deaths caused by HIV/AIDS, with TB as a contributory cause.

b. This indicator is not the same as the SDG indicator for catastrophic health expenditures.

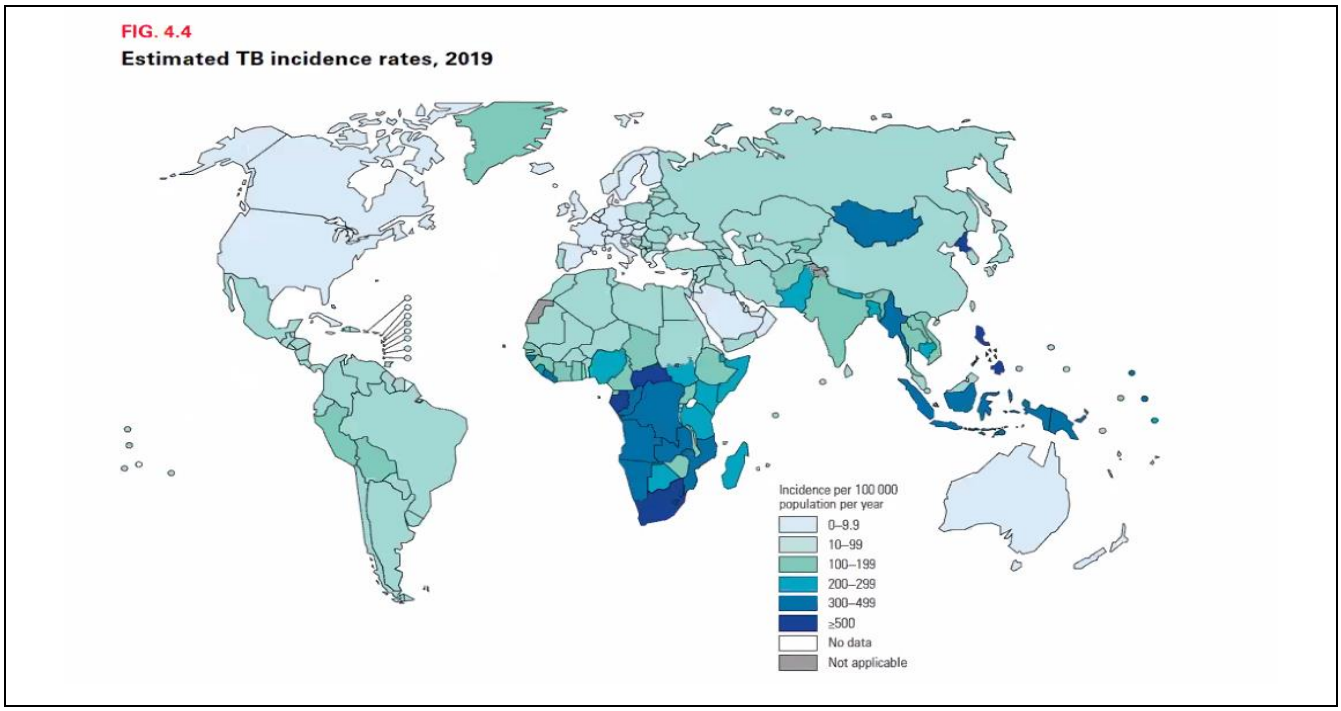
Source: The image was obtained from *Global tuberculosis report 2023*, (p.3), by the World Health Organization, 2023, (https://www.who.int/teams/global-tuberculosis-programme/tb-reports/global-tuberculosis-report-2022).

Ending TB is not just a public health problem, but a development challenge and opportunity. Although the strategy is not a "one-size-fits-all" approach, its success depends on adaptation in diverse countries' settings (WHO, 2023). The WHO has set targets for 2020 to 2035, which require that countries need to reduce TB incidence by 80%, TB deaths by 90%, and to eliminate catastrophic costs for TB-affected households by 2035 as compared to a 20% reduction in TB incidence, and a 35% reduction in the absolute number of TB deaths for 2020 (WHO, 2019).

Figure 4 shows that geographically most TB cases reported in 2018 were found in South-East Asia (44%), followed by Africa (24%) and the Western Pacific (18%). The Eastern Mediterranean (8%), the Americas (3%) and Europe (3%) had smaller percentages. Eight countries accounted for two-thirds of the global total, namely: India (27%), China (9%), Indonesia (8%), the Philippines (6%), Pakistan (6%), Nigeria (4%), Bangladesh (4%) and South Africa (3%). These and 22 other countries in the WHO's list of 30 high-TB burden countries accounted for 87% of the world's cases (WHO, 2020).

Figure 4:

Global Estimated TB Incidence Rates Reported in 2019



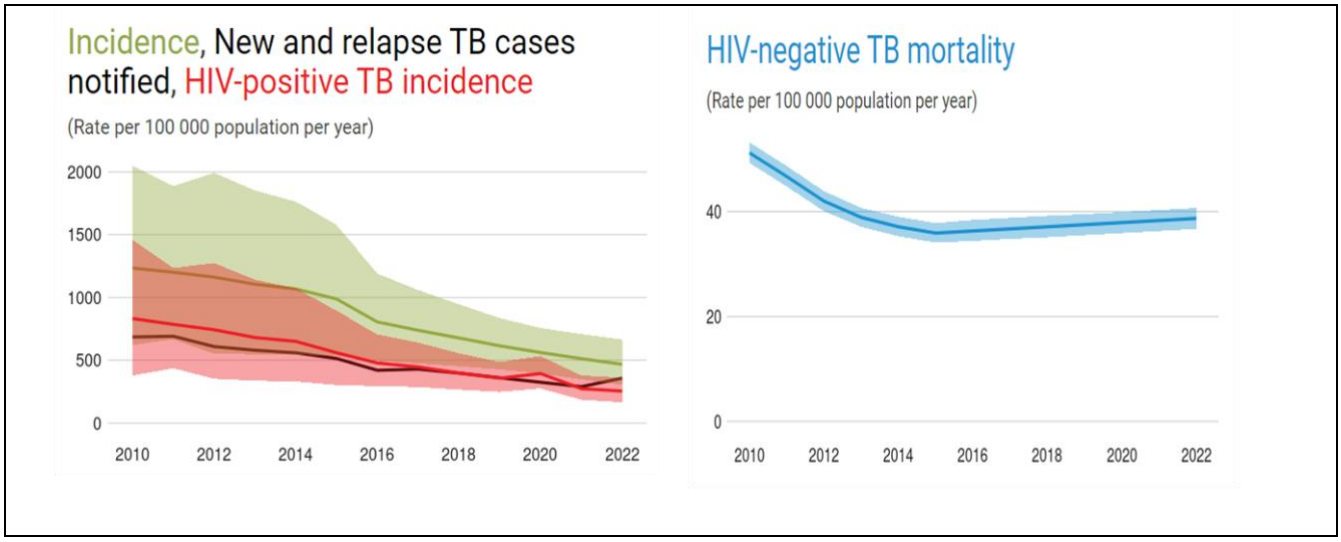
Source: The image was obtained from *Global tuberculosis report 2020*, (p.35), by the World Health Organization, 2020, (https://iris.who.int/bitstream/handle/10665/336069/9789240013131-eng.pdf?sequence=1).

2.2.4 Overall Tuberculosis Statistics in South Africa and the Implications of the COVID-19 Pandemic

Globally, the Covid-19 pandemic has set back the fight against TB by and an estimated decade (WHO, 2021). This is owing to restrictions that disrupted essential TB services. Overall TB profile statistics in South Africa, provided by the WHO in 2022, reported the TB incidence as 280 000 (468 per 100 000 population per year) (see Figure 5). The TB mortality total among HIV-negative patients was 23 000 during the 2022 period (39 per 100 000 population per year).

Figure 5:

Estimates of TB Burden: South African Profile Figures for 2022



Source: The image was obtained from *Global Tuberculosis Programme: Country, regional and global profiles* webpage, by World Health Organization, 2022, (https://worldhealthorg.shinyapps.io/tb_profiles/?_inputs_&entity_type=%22country%22&iso2=%22ZA%22&lan=%22EN%22).

South Africa reported a 50% reduction in the number of TB tests conducted during the initial stages of the Covid-19 pandemic. In addition, a 12% reduction in the targeted TB treatment success rate of 90% was observed (Dheda et al., 2022). The reduction in access to treatment and healthcare services together with the disruption to transport services and treatment completion contributed to the reduction in TB treatment success rate.

To overcome the setbacks brought about by the pandemic, the National Department of Health (NDoH) developed a National TB Recovery plan (April 2022–March 2023) to accelerate TB control efforts and fulfil global commitments to end TB. The plan's key objectives are to locate people in communities with undiagnosed TB disease, strengthen the links between TB diagnoses to care and treatment, strengthen retention in TB care, and improve TB-related data collection and management (South African Medical Research Council, 2023).

Several provinces in South Africa developed aggressive TB-related plans to help monitor the TB response (Jeranji, 2021). An example is the Western Cape province, which launched a public TB dashboard (Western Cape Government, 2023). The TB dashboard includes data on TB cases, deaths, test positivity and drug resistance, all of which dates from 2015 onwards. This was achieved through computer modelling, based on lessons learnt from the global response in the fight against Covid-19. This interactive programme aims to get the TB response in the province back on track (Jeranji, 2021).

Similarly, researchers across the world have called for real-time TB dashboards for recording cases and deaths (Mascarenhas, 2022).

Tuberculosis remains the leading cause of natural death among all people in South Africa, and the leading cause overall among people living with HIV (PLWH) (Naidoo et al., 2019). South Africa is among the eight high-burdened countries that contribute to 58% of new TB cases globally (WHO, 2019). Therefore, if TB is not managed, there will be a continuing increase in transmission of TB infection in South African communities. This is likely to impose serious financial burdens on sufferers due to prolonged treatment, diagnostic procedures, and the use of multiple drugs (Assefa et al., 2024). In addition, this will lead to the increase in the global burden of TB.

The condition is treatable, on condition that patients use their medication as prescribed for the recommended period of six months. If patients fail to adhere to their treatment regimen, this may result in the development of drug-resistant (DR-TB), thereby compromising the treatment and prognosis. Follow-up visits are needed to monitor response and adherence to treatment. In addition, these monitoring visits offer patients the opportunity to report adverse reactions to their treatment. The treatment of drug-susceptible TB (DS-TB) is divided into two phases, namely: 1) the intensive phase, which lasts for two months; and 2) the continuation phase, the last four months of taking a combined course of antibiotics (Nahid et al., 2016).

2.3 MEDICATION ADHERENCE

2.3.1 Medication Adherence Defined and Clarified

Adherence to treatment is a complex subject that is associated with various terminologies like compliance, persistence, discontinuation, all of which are still being used as synonyms or equivalents of adherence (Anghel et al., 2019). Compliance, one of the first terms used, is defined as “the extent to which a patient acts in accordance with the prescribed interval and dose of a dosing regimen” (Anghel et al., 2019, p.118). This definition was labelled as having a negative connotation in that it requires patients to be obedient to healthcare providers’ (HCP) instructions. Since more recently the act of prescribing treatment is viewed as a shared decision between a patient and an HCP as both can influence medicine-taking behaviour (Anghel et al., 2019). For this study, adherence is defined as a person’s behaviour matching the prescribed medical advice of the healthcare provider (Adefolalu, 2018). Adherence is also linked to lifestyle-related recommendations such as taking medications, following diets, or executing lifestyle changes recommended by HCPs (Panahi et al., 2022). This study specifically focused on medication-taking.

2.3.2 Problems Relating to Medication Adherence and the Implications and Consequences of Non-adherence

Medication adherence continues to be an important challenge in healthcare, exacerbated by a shortage of effective interventions (Kvarnström et al., 2021; Nanji et al., 2013; Ruru et al., 2018). Non-adherence can increase healthcare costs through the consumption of medicines below the threshold of adherence required for clinical benefit, and can contribute to healthcare resource use, for example through hospital admissions (Kvarnström et al., 2021; Mongkhon et al., 2018; Nanji et al., 2013). In these cases patients' long-term treatment outcomes are affected. An international study conducted by Fernander-Larazo et al. (2019) in Spain reported that adherence to treatment for chronic conditions remains low in primary care. The proportion of patients adherent to treatment in the Fernander-Larazo et al. (2019) study was 55.5%, as indicated by their research sample. Other meta-analyses and systematic review studies reported adherence rates of around 50% or less (Cheen et al., 2019; Naderi et al., 2012; Nieuwlaat et al., 2014; Petry et al., 2012). Sabaté (2003) further argues that only half of patients with chronic conditions take their medications as prescribed. Improving medication adherence should thus be a public health priority (Sabaté, 2003).

In the context of TB, patients' failure to adhere to TB treatment is also a major challenge as it leads to poor treatment outcomes (Gashu et al., 2021). According to Ruru et al. (2018), complete cure requires six months of treatment with multiple drugs without any interruption. Therefore, this poses a challenge for patients and healthcare workers. Incomplete TB treatment may cause prolonged TB transmission, increased risk of developing drug-resistant TB, relapse, and death (Ruru et al., 2018). Medication non-adherence is not only associated with poorer health outcomes but is one of the most significant obstacles to TB control globally (Gebreweld et al., 2018; Kvarnström et al., 2021). The impact of poor treatment on morbidity, mortality, and disease transmission is aggravated by poverty, weak healthcare systems, and low levels of health literacy found in many low- to middle-income countries (LMICs) (Kruk et al., 2018). Enhancing adherence is thus central to safeguarding both individual and public health (DiStefano & Schmidt, 2016).

Adherence to TB medication is a complex and dynamic matter as it is affected by multiple barriers (Nezenega et al., 2020). The influence of these barriers, often referred to as factors individually and in combination, vary from one social or geographic setting to another. Managing non-adherence to TB medication requires awareness of context and target all the relevant factors (DiStefano & Schmidt, 2016). There are several categories of factors that impact the patients' ability to follow treatment recommendations (DiStefano & Schmidt, 2016; Gebreweld et al., 2018; Sabaté, 2003; Woimo et al., 2017; Nezenega et al., 2020). Six categories of barriers are discussed below, namely: 1)

Illness cognition; 2) structural and healthcare-related factors; 3) quality of communication; 4) medication-related factors; 5) psychological distress and helplessness; and 6) behavioural factors.

2.3.3 Categories of Medication Adherence Barriers

2.3.3.1 Illness Cognitions

Patient-related factors

are characterised by what is called illness cognitions. Rau and Williams (2013) describe illness cognitions as a range of cognitive processes underlying attention, interpretation, and behaviour in response to illness-related information. This personal assessment of health on the part of patients is central to their self-regulatory behaviour (self-care decision-making, communication with healthcare providers, commitment to treatment regimens, etc.) (Rau & Williams, 2013).

Leventhal's (1980) commonsense model of self-regulation (CS-SRM) (see Table 1) indicates that individuals develop cognitive illness representations elaborated around five main components, namely: identity, timeline, cause, consequences, cure or control, coherence, and emotional representations (Leventhal et al., 1980). It is important to understand that Leventhal's self-regulatory model is useful for gaining insight into how people think of their illness and how this affects their adherence to therapeutic regimens and health outcomes (Leventhal et al., 2003; Leventhal et al., 2007; Leventhal et al., 2016; McAndrew et al., 2007).

Table 1:
Definitions of Common SENSE Model of Self-Regulation (CS-SRM) Constructs

CS-SRM Constructs	Definitions
Identity	Refers to the category, name or label, and the experience of symptoms, changes in function and visible signs. The combination of abstract and concrete experiential features "define" or identify the disease (Leventhal et al., 2007).
Timeline	The duration that can be expected or perceived with respect to the onset and duration of an illness both with and without effective treatment. Timelines are represented abstractly as clock and calendar time and concretely as experienced or felt time (Leventhal et al., 2007).
Cause	Reflects the perception of the single or complex set of events that are perceived as responsible for disease onset (Leventhal et al., 2007).
Consequences	The set of expected and perceived physical or functional, personal, and social and economic factors on which the illness has an impact (Leventhal et al., 2007).
Cure/control	Refers to the expectation that a specific disease can be cured or controlled by the body's own defences or in conjunction with expert intervention, and the actual experience of the effects of these interventions on specific features (symptoms or test results) of disease (Leventhal et al., 2007).
Coherence	Whether or not people understand or have a clear picture of their illness (Moss-Morris et al., 2002).
Emotional representation	An emotional representation generated by the illness (Moss-Morris et al., 2002).

Source: (Leventhal et al., 2007; Moss-Morris et al., 2002).

According to Astin and Jones (2006) illness misperception has negative effects on patients' behaviours such as adherence to treatment, self-diagnosis, help-seeking behaviour, and outcomes of the disease. In South Africa the problem of illness misperceptions is big, firstly the myths around TB only affecting certain groups of people, such as those who live in poverty, secondly that TB is extremely contagious and lastly there is low TB knowledge. Although people have a general idea of what TB is, gaps continue to exist in knowledge on transmission, treatment, and prevention (Matakanye et al., 2021). This problem requires increased efforts in public awareness and health promotion on TB knowledge. Furthermore, patients' perception of the disease (based on the beliefs and perceived knowledge of their condition) can affect their mental health and how they deal with the disease (Yaraghchi et al., 2012). TB patients perceived their illness to be of long duration. It is common for some patients with TB not to have visible symptoms and feel well, particularly during the continuation phase of the treatment (after the initial two-month, clinic-based treatment period). The latter is a factor for non-adherence and loss to follow up because patients perceive themselves to be well and cured (Nezenega et al., 2020). In addition, patients mistakenly assume that if they do not feel ill, (have no cough/night sweats/loss of appetite/feeling tired/weight loss/generally not feeling well), that it means they are not sick, so why would they take medication. For those TB patients who experience TB symptoms, they may feel guilty that they might infect others and thus aggravate the sense of stigma. These thought processes link to illness cognitions, particularly the timeline and cure or controllability of the condition, for example, whether TB is curable, as well as which symptoms patients associate with the disease.

Illness perceptions shape the mental experience of living with an illness. For example, positive or negative beliefs about the disease can affect the ability to cope with the disease and perceive it as manageable or threatening (Saranjam et al., 2023). TB patients who are highly concerned about their illness tend to have poor mental quality of life. For example, depression and anxiety have been identified as very high in patients with tuberculosis – this affects their quality of life and adherence to treatment which results in loss to follow-up (Mohammedhussein et al., 2020). Therefore, through cognitive and emotional responses, illness perceptions can increase patients' motivation to improve their lifestyles and influence how well they adjust (van Broekhoven et al., 2017). In addition to illness cognitions, structural and healthcare-related factors can also have an impact on adherence behaviour.

2.3.3.2 Structural Factors and Healthcare-related Factors

Poverty and difficulties with travelling to the healthcare facilities are structural factors in developing countries that form barriers to medication adherence and are harder to overcome. Poverty can have an impact on adherence, for example, where treatment costs are not covered. Poor patients or those

supporting patients then have to choose between going to work and looking after their health (DiStefano & Schmidt, 2016). This issue can be overcome by offering free TB treatment at health facilities and food parcels for those on treatment. A study conducted by Vanleeuw et al. (2022) on food insecurity and access to social protection for TB patients and their households in Cape Town, South Africa reported that access to adequate nutritious food and state social protection support during the TB illness was important for many patients. However, access to the state social protection support itself comes with high costs. For example, TB patients reported challenges associated with the application process and the high levels of discretion by the assessing doctor allowing doctors' opinions and beliefs to influence their assessment (Vanleeuw et al., 2022).

Distance of the health facility from home relates to transport costs. Therefore, healthcare facilities that are geographically inaccessible from residences prevent patients from keeping their regular clinic appointments and receiving follow-up treatment. This can result in non-adherence and defaulting of treatment (Marahatta et al., 2020; Nezenega et al., 2020). A study conducted by Kahere et al. (2022) at five public hospitals in KwaZulu-Natal, South Africa, show that the burden of travel to and from the healthcare facility was one of the most concerning barriers to accessing healthcare facilities. This was due to outpatients often booked for multiple visits to the facility (follow-up treatments or because pain was not going away). In addition, lack of efficient emergency transportation services (ambulances) worsens the situation, forcing patients who are financially struggling to hire private vehicles (Kahere et al., 2022). The study indicates that this issue remains a major problem. Furthermore, this issue is recognised and forms part of the third target of the End TB Strategy, that no TB patients and their households should face catastrophic total costs because of the disease. "Catastrophic" is defined as direct medical expenditures, direct non-medical expenditures, and indirect costs (loss of income) that comprise more than 20% of household income (WHO, 2023). To resolve the transportation costs incurred by TB patients every time they need to access the healthcare facilities, the delivery of treatment to TB patients at their homes can possibly be explored. Patients who adhere to treatment, whose sputum culture conversion after two months of treatment is negative and who do not experience adverse drug effects should be treated differently according to their needs (i.e. have less clinic visits). TB should consider following an approach similar to the differentiated model of care for HIV.

Inadequate drug stocks, long waiting times, inconvenient service hours, lack of support and empathy by healthcare providers have also been identified as barriers of adherence to TB treatment and can lead to the discontinuation of care (DiStefano & Schmidt, 2016; Kvarnström et al., 2021; Marahatta et al., 2020). In relation to empathy, the aspect of communication between the patient and healthcare provider can have a significant effect on adherence. What is currently being done to address these issues include the implementation of the universal health coverage, which is a starting point for

improving the quality of health systems. There are trainings in the pipeline which will be offered to all health workforce members, such as competency-based clinical education, training in ethics and respectful care to enable the delivery of best care (Kruk et al., 2018). The issue of drug stockouts is not exclusive to South Africa; however, the National Department of Health has rolled out a range of electronic surveillance systems to monitor medicine stocks throughout the country's healthcare facilities (Copelyn, 2023). Although many healthcare workers feel the new systems are making a positive impact, the stockouts remain owing to a host of ongoing supply challenges (Copelyn, 2023).

2.3.3.3 Quality of Communication

The quality of communication essentially determines the nature of the patient–provider relationship. Patients who perceive a provider or healthcare professional as treating them with warmth and empathy are more likely to regard the professional as competent, which then translates into improved adherence (Kwame & Petrucka et al., 2021). In contrast, if patients feel they are treated without any emotion or personal care, they may regard the professional as incompetent, which translates into non-adherence. Communication may therefore increase the burden of the illness and have an essential influence on a patient's adherence behaviour (Kvarnström et al., 2021). A study conducted by Chandru and Varma (2023) in India on factors affecting the ability of TB patients to follow treatment guidelines showed meaningful results. In that study, patients who felt that they were supported in their treatment by healthcare providers expressed that they felt being seen, acknowledged, listened to, responded to when they had doubts, and were respected in terms of privacy and confidentiality. In addition, respect and good communication facilitated trust (Chandru & Varma, 2023). It can be concluded that the emotional component experienced by patients in relation to the healthcare service they receive (including satisfaction) is important. Furthermore, other technical aspects of care that are likely to influence patients to become non-adherent includes perceptions regarding less than professional care and long waiting hours to get the healthcare service (Nezenega et al., 2020).

2.3.3.4 Medication-related Factors

Patients at the onset of their illness may lack information on the medication they will have to take, therefore treatment may seem to be time-consuming and complex. A risk factor for medication adherence that can easily lead to missing doses or sleeping through dosing times is forgetfulness. In this context, forgetfulness is related to the lack of routines, being busy with work, being away from home for work or other social-related activities and experiencing difficulties in integrating medication into daily life (Kvarnström et al., 2021; Nezenega et al., 2020). Furthermore, patients' motivation to adhere to medication is also affected when they associate taking medication with being sick, consider the medication not being safe, regard medication-taking as unpleasant (size of the tablet makes it

difficult to swallow or leaves an after-taste or causes throat pain), and experiencing side effects (including fever, fatigue, weakness, nausea, vomiting, hepatitis or death) (Adisa et al., 2021; DiStefano & Schmidt, 2016; Kvarnström et al., 2021).

In relation to the actual medication and prescription, other studies (Aibana et al., 2020; Mekonnen & Azagew, 2018) found that the high pill burden of TB treatment undermined adherence. In addition, during the continuation phase of treatment, in the aforementioned study patients experienced improved symptoms of the disease and could possibly have interpreted their condition as cured. This contributed to carelessness in taking medications and resulted in the continuation phase of treatment being significantly associated with non-adherence (Mekonnen & Azagew, 2018). Essentially, it can be argued that patients' adherence declined when they were prescribed complex TB treatment. This explains why patients with poor awareness about the need to take medication as prescribed may seek to adjust their doses according to their own understanding (Kvarnström et al., 2021). Therefore, an education component associated with prescribing TB medication may be useful in improving adherence. Patients need to be educated on each medication, including its own risks for adverse effect and potential drug interactions (for example, rifampicin interacts with many drugs, including hormonal birth control, making them ineffective). In addition, the importance of completing the entire course of treatment needs to be emphasised at every visit, irrespective of the patient's feeling better (especially during the continuous phase of treatment) to avoid developing drug resistance. In addition to medication-related factors, patients' psychological distress, helplessness, and behavioural factors associated with adherence behaviour, are outlined in the section that follows.

2.3.3.5 Psychological Distress and Helplessness

Drapeau et al. (2012) define psychological distress as a state of emotional suffering that is characterised by symptoms of depression and anxiety. In addition, psychological distress can affect individuals' ability to care for their own health and can cause chronic and physical disability (Veggi et al., 2004). Research suggests that the combination of psychological distress and other medical conditions has an impact on several health outcomes and adherence to medication is one of them (De Hert et al., 2011; Moore & Posada, 2013). For example, individuals with psychological distress are at greater risk of treatment non-adherence (de Hert et al., 2011; Hüther et al., 2013).

In the context of tuberculosis, psychological distress is common due to the social and medical risk factors (Doherty et al., 2013). Peltzer et al. (2012) emphasised that psychological distress among TB-infected patients on treatment in developing countries is high. A study conducted in Russia on factors influencing diagnostic delay among patients with TB found that the main contributing factor to unsuccessful health-seeking behaviour in patients with TB was being overcome with hopelessness. As

a result, this state of hopelessness affected the patients' self-esteem, which had a ripple effect on their family life, work and social relations (Kuznetsov et al., 2013). A sense of hopelessness reflected the passive position of many TB patients in this situation, including their feelings of inability to change anything in their lives (Kuznetsov et al., 2013). Naidoo and Mwaba (2010) found among people with TB attending a public health clinic in the Cape Metropolitan area that the psychosocial factors feelings of helplessness, depression, and inadequate social support had a negative influence on adherence to treatment. A study conducted in Ethiopia on the magnitude of psychological distress and its effect on treatment outcome among TB patients found that levels of psychological distress was high, and was further associated with their low economic status. Therefore, it was recommended that screening and treatment of psychological distress be implemented among TB patients across the treatment duration, specifically among those patients who are economically deprived (Tola et al., 2015). In addition, Nezenega et al. (2020) reported on a qualitative study conducted in Addis Ababa that the poor mental health status of patients contributed to their reluctance to attend follow-up and clinic appointments regularly.

2.3.3.6 Behavioural Factors Influenced by the Locus of Control

Health locus of control is recognised as a factor affecting the development and promotion of health behaviours (Dogonchi et al., 2022). It is believed that the amount of control a person has over specific events in their life ultimately predicts their health behaviour (Náfrádi et al., 2017). There are two types of health locus of control, the external and the internal locus of control. People with an external locus of control believe that the events that happen in their lives are the result of external factors such as fate, luck, and the influence of powerful others (doctors). External locus of control is illustrated by patients who have an adverse emotional reaction to TB (Anderson et al., 2018). These patients perceive TB disease as an unwanted episode, meaning they do not accept it and believe it is someone else's fault. In contrast, people who have an internal locus of control believe that their own abilities, actions, and behaviours directly influence their health outcomes (Hashemian et al., 2015). People who feel responsible and self-empowered, and have a strong belief in their ability to complete treatment, have a positive attitude to medication adherence (Kvarnström et al., 2021). According to theory, people with an internal locus of control follow positive health behaviours, while those with an external locus of control tend to engage in negative and poor health behaviours (Hairaty et al., 2019). It is therefore important to focus on people's beliefs about the influence of internal factors and increase awareness about their ability to promote their own health behaviours (Fathabadi et al., 2018). Health locus of control ultimately relates to a person's views about who is in control of their health. When this locus is internal a person regards themself as responsible, so they make better health choices and commit

more to treatment compared to someone with an external locus, who feels that the condition is due to external factors and that someone else needs to take care of their health issue.

In addition to psychological factors influencing medication adherence behaviour, self-efficacy and stigma have been recognised as significant predictors of adherence behaviour (Adefolalu et al., 2014; Huang et al., 2013; Náfrádi et al., 2017).

2.3.3.6.1 Self-efficacy

Self-efficacy, according to Bandura (1989), is an individual's personal beliefs regarding their capability to carry out a specific task to achieve a desired outcome. An individual's self-efficacy may be related to their independent construal of the self. Other researchers have found that the individual's independent construal of the self is positively related to self-efficacy (Suryaningrum, 2018). Furthermore, Bandura's social cognitive theory (SCT) suggests that self-efficacy influences motivation and the ability to engage in self-care behaviours (Bandura, 1986; Tan et al., 2021). In addition to this theory, personal cognitive and affective factors such as belief and self-efficacy, and environmental factors such as social support contribute to a dynamic, ongoing process that influences self-care behaviour. Individuals with high self-efficacy are more likely to engage in self-care behaviours and maintain them over time, irrespective of obstacles that prevent them from performing these behaviours (Bandura 1986, 2013). It can therefore be argued that enhancing self-efficacy will result in improved self-care behaviours among affected individuals. In the context of medication adherence, the patient believes in their ability to continue taking medication despite various challenges that may be encountered. A high sense of efficacy can be associated with better health outcomes, greater achievement, and better social integration (Kvarnström et al., 2021).

According to Gallagher (2012), self-efficacy theory does not suggest that positive self-efficacy beliefs are the only causes of important outcomes. Instead, self-efficacy theory is rooted in a theory of triadic reciprocal determinism that is characterised by a constant interplay between personal factors (self-efficacy beliefs), behaviour, and environmental factors. Therefore, self-efficacy theory highlights the relative importance of personal factors, but at the same time acknowledges that behavioural and environmental factors have a profound effect on outcomes (Gallagher, 2012). In essence, if the effects of the environment are consistent (an even playing field for all), then self-efficacy beliefs will assume an even greater role in determining human behaviour, and ultimately in shaping outcomes (Gallagher, 2012).

Differences in patient motivation and willingness in relation to self-efficacy can hinder adherence (DiStefano & Schmidt, 2016; Kvarnström et al., 2021; Nezenega et al., 2020). If, however, the patient

perceives the TB disease (this includes medication, wellness or cure, risk, and barriers over the benefits) as something they cannot control, they are more likely to be non-adherent to TB medication (Kvarnström et al., 2021; Nezenega et al., 2020). Patients' lack of information or knowledge of TB at the beginning of treatment (despite medication information and adherence counselling offered by the healthcare provider) may cause them not to believe in their own abilities to follow the treatment.

Self-efficacy is an important skill when coping with practical problems in daily life. In relation to TB patients, taking ownership to self-manage the medication increases the chances of better adherence (Kvarnström et al., 2021). A study conducted by Aregbesola and Adeoye in 2018 investigated HIV-treatment adherence self-efficacy and antiretroviral therapy (ART) adherence among 126 HIV-positive, pregnant women in South-West Nigeria. The HIV-Treatment Adherence Self-efficacy Scale and the Centre for Adherence Support Evaluation Index Tool were used to measure the study's constructs. The results showed that low HIV-treatment adherence self-efficacy was related to poor medication adherence, therefore highlighting the value of self-efficacy in adherence to HIV treatment (Aregbesola and Adeoye, 2018). Other research studies (Holloway & Watson, 2002; Lim et al., 2021; Martono et al., 2023) on adherence and self-efficacy show similar results to those of Aregbesola and Adeoye (2018). These studies found that adherence to pulmonary tuberculosis treatment is highly dependent on optimal self-efficacy (Martono et al., 2023). In addition, self-efficacy has been identified as a significant predictor of current health behaviour, future health behaviour, and change in health behaviour (Holloway & Watson, 2002). Lim et al. (2021) posit that by increasing self-efficacy and empowering patients to make informed decisions about how they receive TB-preventive therapy, the goal to complete treatment can be achieved. Future research needs to apply context-specific self-efficacy measures for predicting medication adherence (Náfrádi et al., 2017).

2.3.3.6.2 Stigma

Stigma is understood as an attribute that a person possesses (or is believed to possess) that is devalued or discredited in a particular social context (Crocker et al., 1998; Feldman & Crandall, 2007; Goffman, 1963). Subu et al. (2021) indicate that in general stigma leads to negative social experiences such as isolation, rejection, marginalisation, and discrimination. Thus, if stigma is related to a health condition such as mental illness, it may affect a person's illness and treatment course, including access to appropriate and professional medical treatment (Subu et al., 2021). Furthermore, stigma is also linked to illness cognitions and consequently patients may erroneously assume that they will be judged by others if they take their medication in front of them, while watching them. Although stigma is strongly influenced by cultural and contextual value systems that differ over time and across contexts, most authors agree with Goffman's basic elements of stigma, which is labelling, stereotyping, social isolation, prejudice, rejection, ignorance, loss of status, low self-esteem, low self-efficacy,

marginalisation, and discrimination (Ahmedani, 2011; Corrigan et al., 2005; Corrigan et al., 2006). In the context of mental healthcare, stigma has been identified as a major issue for patients and families. The impact of stigma and the prejudice patients encounter has been equated with the negative symptoms associated with their disorder, and becomes a burden on their private and public lives (Gluck et al., 2019).

Corrigan (2004) identified two types of stigmas associated with mental health and psychological services: public stigma (enacted) and self-stigma (internalised). It is important to highlight that stigma is also related to some medical conditions (HIV, TB, etc.) and disabilities (not only mental health). Public stigma is referred to as the act of discriminating against individuals with the specific characteristics or attributes. Public stigma influences the development of self-stigma (Vogel et al., 2007) to an extent that individuals with mental illnesses experience a decreased intention to seek help and have limited capacity to establish positive attitudes about themself (Vogel et al., 2013). Self-stigma is the act of personally internalising the public stigma being displayed by other people and the stereotypes surrounding mental illness (Corrigan, 2004; Corrigan et al., 2010). However, as self-stigma is heavily influenced by public stigma, higher public stigma can result in higher self-stigma (Vogel et al., 2006, 2017). Furthermore, studies conducted in rural China and Ethiopia have shown that experienced stigma is significantly associated with psychological distress (Ayana et al., 2019; Xu et al., 2017). TB patients who feel stigmatised may be less likely frequently to use health services and will try to conceal their illness because of low self-esteem and social isolation (Chen et al., 2021). Low adherence to medication can be influenced by psychological factors, one of which is self-stigma (Akbar et al., 2020).

Both enacted and internalised stigma are experienced by people diagnosed with TB. Internalising the stigma may increase the risk of mental and physical health problems, which can have negative consequences for treatment adherence (Blake Helms et al., 2017). Studies have found that internalised stigma results in treatment avoidance and decreased participation in treatment (Corrigan, 2004; Corrigan et al., 2010; Vogel et al., 2013). In addition, internalised stigma (including self-stigma) is linked to increases in psychological distress and poorer quality of life (Cheng et al., 2019; Moya et al., 2014; Sarkar et al., 2019). According to DiStefano and Schmidt (2016), real or perceived stigmatisation of the sick can hinder adherence. Patients may not want anybody to know about their illness due to the fear of being stigmatised. The fear can be so intense that the patient would prefer not to take medication if there is a possibility that someone might be watching (Kvarnström et al., 2021). Therefore, internalised stigma has been identified as a risk factor for early treatment interruption (Ifebunandu & Ukwaja, 2012; Hassard et al., 2017). Tuberculosis patients' behaviour in response to social discrimination has contributed to diagnostic delays, non-adherence, and the abandonment of treatment,

resulting in an increased number of multidrug-resistant tuberculosis cases (Burtscher et al., 2016; de Almeida Crispim et al., 2017; Kamaradova et al., 2016; Marahatta et al., 2020; Mhode & Nyamhanga, 2016). It is of key importance to note that some TB patients experience the suppression of self-esteem secondary to stigmatisation, which contributes to treatment avoidance (Chen et al., 2021; Kastien-Hilka et al., 2017). More research is warranted using validated instruments to quantify the impact of stigma on treatment compliance (Courtwright & Turner, 2010).

In the context of technologies used to control TB, Craig et al. (2017) highlight the fact that their use in diagnostics and treatment have been implicated in the social construction of stigma and can further reinforce stigma and stigmatising practices. This intersection between technological innovations and the implementation settings at times have unintended consequences. For example, HIV rapid tests that, due to their rapidity and ease of use, allow some private doctors to test for HIV without the patient's knowledge, further reinforces the existing stigma that prevents patients agreeing to HIV testing (Engel et al., 2015). Similarly, patient treatment cards that identify patients as co-infected with HIV and TB through their colour (Kwapong et al., 2014), or DOTS treatment schedules that expect patients to attend a TB clinic in their community daily, can reinforce existing stigma (Craig et al., 2017). The use of the pillbox can extend the experience of stigma for the patient as carrying the pillbox is associated with the fear of being identified as someone suffering from a chronic illness, which might indicate poor adherence to treatment (Ndege et al., 2022; Paschoal et al., 2014).

2.4 LANDSCAPE OF TB ADHERENCE TECHNOLOGIES

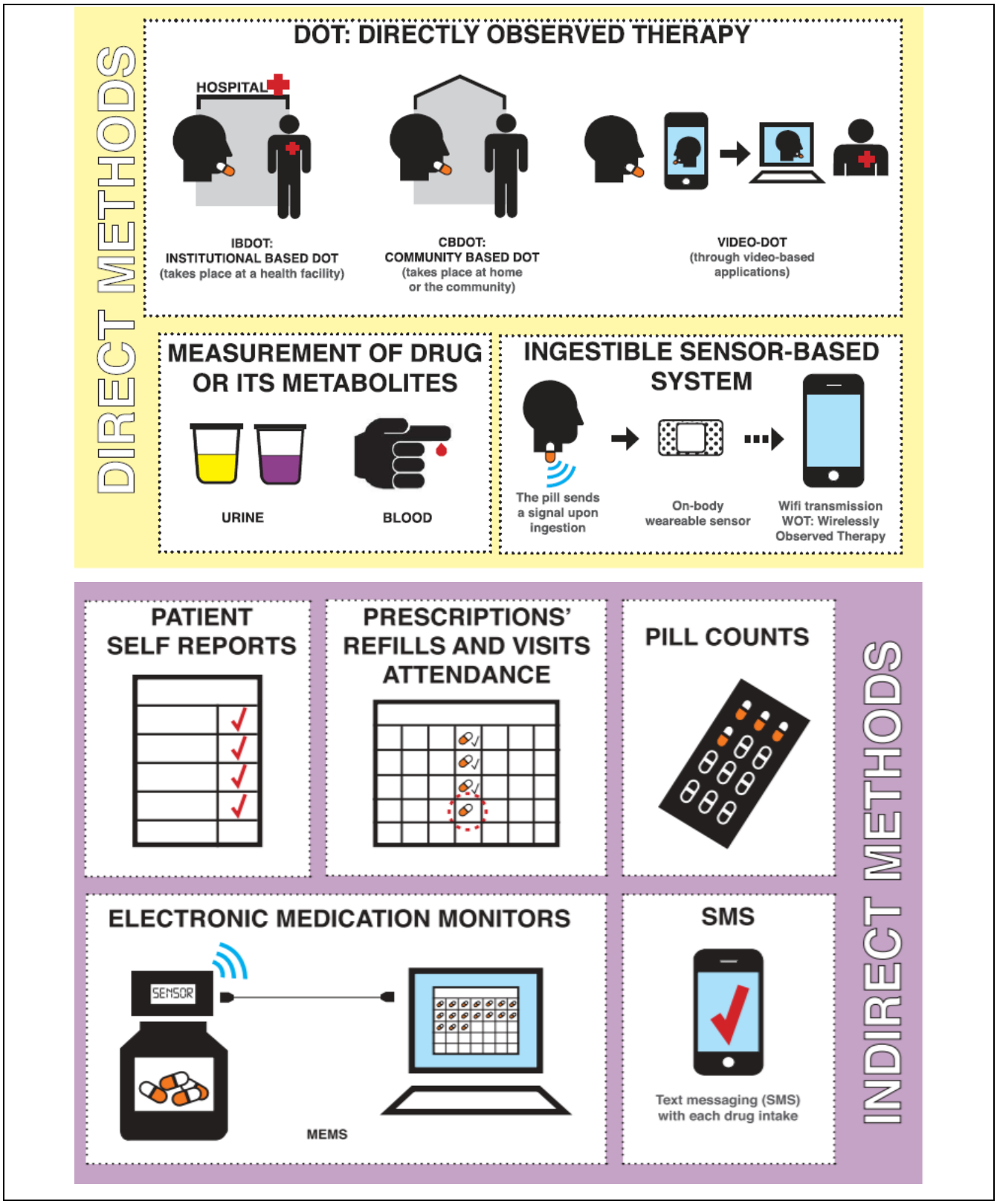
2.4.1 Classification of Measures of Adherence

Identifying non-adherent patients to treatment requires the use of different methods that have been developed and validated across multiple settings. In general, they are commonly classified into direct and indirect methods (Anghel et al., 2019; Valencia et al., 2017). The WHO also classifies adherence assessment methods into direct (objective) and indirect (subjective) methods (Sabaté, 2003). Direct methods refer to measurements of clinical outcomes, dose counts, pharmacy records and electronic monitoring of medication administration. Objective methods seem to have the best potential to measure treatment adherence (Anghel et al., 2019). Indirect methods involve the patient's own assessment of their medication-taking behaviour or the healthcare provider's assessment (usually with the help of a questionnaire). The limitation with indirect measures is that they are inclined to contain a certain degree of bias.

Valencia et al. (2017) also argue that the essence of direct methods is to provide evidence that the patient has taken medication, in contrast to indirect methods, which are used as proxy measures of medication intake (see Figure 6).

Figure 6:

Methods for Assessing TB Medication Adherence



Source: The image was obtained from the paper *How do we measure adherence to antituberculosis treatment?* (p.3), by Valencia et al., 2017, (http://dx.doi.org/10.1080/14787210.2017.1264270).

2.4.1.1 Direct Methods

Direct methods refer to "the direct observation of therapy or measurement of the drug (or metabolite) or biological marker levels in blood or urine, that verifies that the medication has been taken by the patient" (Anghel et al., 2019, p.121). It is similar to objective measures. Examples of direct methods include the following:

- Directly observed therapy is one of the most used adherence interventions, in which a health worker, family member, or community member observes the patient taking TB medications as scheduled (Alipanah et al., 2018).
- Detection of drug and metabolites' concentration in urine, blood, and hair. The method is used to assess adherence to TB treatment by inspecting body fluid (urine) sample for colour change to detect the presence of the drug (or a metabolite) concentration. An example of such a point of care test is the IsoScreen (GFC Diagnostics, UK), a commercial toolkit that quickly detects isoniazid (INH) metabolites in urine for up to 30 hours after the INH ingestion (Mkopi et al., 2014; Soobratty et al., 2014), with a sensitivity between 83% and 93% and a specificity over 95%.
- Ingestible sensor-based system is another novel method for directly measuring medication adherence (Tibble et al., 2021). The sensors are placed within pills and the signal is detected upon ingestion by an on-body wearable sensor, which records date and time of every event. In some instances, sensors for pill ingestion can be coupled with mobile technology, allowing wirelessly observed therapy (WOT) as a replacement for DOT.

2.4.1.2 Indirect Methods

Indirect methods "involve patient questionnaires, patient self-reports, pill counts, rates of prescription refills, assessment of patient's clinical response, electronic medication monitors, measurement of physiologic markers, or patient diaries" (Anghel et al., 2019. p.121). These are similar to subjective measures. According to Lam and Fresco (2015), indirect methods are more popular in adherence research.

2.4.1.2.1 Patient Self-reports

Self-reported methods are among the most affordable and simple procedures for measuring adherence. Whether they are distributed online, administrated as structured interviews, or written questionnaires,

they are characterised with a high degree of popularity in adherence research and can easily be adapted for different patient populations (Forbes et al., 2018). Patient self-reports are generally perceived to overestimate adherence in comparison to direct methods because patients can be influenced by recall or reporting bias (Anghel et al., 2019).

Patient self-reports are often used in the clinical setting. Examples include questionnaires, scales, interviews, and patient diaries. Questionnaires are used broadly and most of them are not TB-specific. The most common questionnaires are: the Morisky medication adherence scale (MMAS) (Méda et al., 2014; Mkopi et al., 2014; Nezenega et al., 2013; van den Boogaard et al., 2011), the brief medication questionnaire (BMQ) (van den Boogaard et al., 2011), and the medication adherence rating scale (MARS) (Farmer, 1999).

One of the main limitations of self-reporting adherence studies is the lack of reliability (Das et al., 2015; Herrero et al., 2015; Kulkarni et al., 2013; Mkopi et al., 2014; Nackers et al., 2012; Yin et al., 2012). This can be explained by patient recall bias and other information biases (O'Donnell et al., 2014; Van den Boogaard et al., 2011; Zhou et al., 2012), social desirability (providing answers that would fit the researcher's expectations), or the interviewer's skills and construction of the questions (Nackers et al., 2012). A close relationship between the patient and the healthcare professional could also result in an overestimation of adherence rates (Adane et al., 2013; Amuha et al., 2009).

Despite these limitations, self-reporting measures are inexpensive, easy to perform and can assess quantitative and qualitative information. Mkopi et al. (2014) showed that a single adherence question on missed doses in the last two days before the interview improved results for identifying adherent patients compared to the use of the INH urine test, but with low specificity in detecting non-adherents. The authors also recommended that measures based on trust give the responsibility to the patient and improve communication (Mkopi et al., 2014).

2.4.1.2.2 Pill Count Method Used to Monitor Adherence

Pill count is a simple method that calculates the number of doses that have been taken between appointments and compares this with the total number of doses that the patient received. An adherence ratio is then calculated. For example, patients are asked to bring blister packs or pill bottles with any remaining pills to their scheduled clinic visits. The number of pills remaining is then compared with the total number of pills provided during their last visit. The time frame for visitations can vary from weekly to monthly depending on the phase of treatment. Therefore, this method is straightforward (easy to perform), inexpensive and can easily be applied for different type of formulations such as tablets and inhalers) (Lam & Fresco, 2015). However, its accuracy can be undermined by recall bias

(patients often not remembering how many pills they had received at the last refill visit or forget to bring blister packs to visits), by practitioner mistakes (errors in pill counting or including other pills in the anti-TB pill count), and behavioural changes prior to visits (Maciel et al., 2008; Nackers et al., 2012).

Lam and Fresco (2015) continue to critique the aforementioned method for not giving specific information about daily adherence and patterns of adherence. Furthermore, the pill count method assumes that by removing the correct number of tablets from the dosing unit is equivalent to taking the medicine as recommended. However, this assumption does not prove actual ingestion of the drug (Lam & Fresco, 2015). Patients can deliberately dump medication before their visits, thus compromising pill count and the potential improvement of adherence around the visit days (Gomes et al., 2011; Lam & Fresco, 2015).

2.4.1.2.3 Prescription Record Review and Other Health Information Systems

According to Andrade et al. (2006), data derived from monitoring adherence to the prescribed therapy in chronic diseases such as hypertension or diabetes is obtained from widely used health information systems. The health information system (HIS) provides the foundation for generation of quality data and is the building block of the health system because it integrates collection, processing, reporting and the use of information required for improving the effectiveness and efficiency of health services. This as a result enhances management at all levels within the health system (WHO, 2007). In recent times the requirement of better and more timely health and health-related information has been driven by the need to be more responsive to emerging and urgent health threats (WHO, 2008).

The common three measures used to calculate adherence through data derived from the administrative databases include medication possession ratio (MPR), the ratio of medication supplied days divided by the days between the first fill and the last fill of the medication, and proportion of days covered (PDC) refers to the proportion of days covered by medication availability within a specified period of time, as well as cumulative medication gap (CMG), which represents the number of days in which the medication was not available, divided by the number of days between the first and last medication refill (Hess et al., 2006).

Limited studies (Alobu et al., 2014; Chirwa et al., 2013; Kayigamba et al., 2013; Ong'ang'o et al., 2014) exist in which data from prescription records or other health information systems was used to describe adherence to anti-TB treatment. A study conducted by Juan et al. (2006) was the closest as it compared DOT with self-administered treatment (SAT), embedded in a pre-existing pharmacy network system. The accuracy of the data from health information systems is dependent on the quality

of the platform. Therefore, if the platform is reliable, data from the health system could be a useful tool for monitoring programmatic goals, and providing long-term information on a substantial number of patients (Valencia et al., 2017). Health information systems can also have advantages over medical reports as standardised information is not always retrieved. A study conducted in Rwanda, for example, found 20% of missing data when retrieving TB data from registers and individual treatment history charts (Kayigamba et al., 2013).

2.4.1.2.4 Electronic Monitoring (Pill Bottles/Boxes) and Text Messaging

Electronic monitoring devices (EMD), also known as a medication event monitoring system (MEMS), provide precise and detailed history about the number of doses taken and other deviations from the dosing regimens. Tibble et al. (2021) divide MEMS into three types: (1) Electronic pill bottles or boxes, both types of EMD, which monitor and record the history of the patient's prescribed medication each time they are opened. In the case of pill boxes, they also use sound or light effects as reminders; (2) 99Dots, when dispensing a dose of TB medication from the blister pack reveals an unpredictable toll-free number to which the patient places a call; (3) Short message service (SMS) systems, when patients confirm that they have taken their medication by sending a message to their healthcare provider (Tibble et al., 2021). Opening an electronic pill bottle or box is assumed to correspond with the ingestion of the medication. However, like any indirect method, it cannot ensure the actual ingestion of the pill (Nackers et al., 2012) as any incorrect use of the device and repeated opening may affect its accuracy. A scoping review study conducted by El Alili et al. (2016), summarised evidence of all studies comparing the MEMS with alternative methods (self-report, pill count and rating by others) for measuring medication adherence. Compared to MEMS, median adherence was grossly overestimated, by 17% using self-report, by 8% using pill count and by 6% using rating (El Alili et al., 2016). Electronic monitoring was nevertheless reported to have high validity (Denkinger et al., 2013).

A medication event monitoring system is less invasive to patients' behaviour compared to other methods and allow for long-term adherence evaluation (Valencia et al., 2017). In addition, MEMS, when coupled with mobile technology, can provide real-time information of patients' adherence (Valencia et al., 2017). Using MEMS in large populations is limited by the relatively high price of the device, and some practical issues such as potential complications that may arise with refilling the prescription at the local pharmacy or with some medication formulations (El Alili et al., 2016). Wisepill technology is an electronic pillbox that monitors real-time adherence and plays an important role in identifying early adherence lapses prior to TB treatment failure (Bangsberg & Deeks, 2010). Furthermore, when wisepill is incorporated in a patient-centred model of improving adherence; it contextualises missed doses in the clinical, socioeconomic, and structural factors surrounding this highly stigmatised group (drug-resistant tuberculosis and HIV patients) (O'Donnell et al., 2014). The

Bionghi et al., (2018) study evaluated the accuracy and acceptability of a next-generation electronic pillbox (Wisepill RT2000) for Bedaquiline-containing TB regimens over a period of three weeks. The findings illustrated that wisepill was more sensitive (100%) when compared to seven-day recall (0%) in detecting non-adherence events ($p = 0.02$) (Bionghi et al., 2018). The wisepill box has also been used in other contexts to improve adherence in other diseases (such as HIV) (Dworkin et al., 2019; Ngowi et al., 2022; Reid & Dale, 2022).

Several methods have been discussed to estimate adherence and quantify the impact of programmes aimed at increasing adherence as no method exists that is regarded as the "gold standard". Anghel et al. (2019) recommend selecting at least two methods that can give results that are closer to reality: an objective method, which is usually more expensive and invasive, which gives solid proof of the ingestion of medication, and a subjective method, which is easy to implement and inexpensive but lack reliability and accuracy. The aforementioned methods can be accompanied by information regarding factors, beliefs, or barriers to adherence (Anghel et al., 2019). The reason for this is the lack of a standard definition of good adherence, but different thresholds for error are nevertheless used in various studies (Anghel et al., 2019; Mason et al., 2022).

2.4.2 Challenges with Measures of Adherence to TB Medication

Currently, there is no gold standard for measuring patients' adherence to treatment owing to the variation in definitions of adherence (Mason et al., 2022). Therefore, different studies are generally tailored to assess specific interventions, which makes generalisation and comparison rather difficult (Andrade et al., 2006).

Direct observation of the patient's medication-taking behaviour by healthcare practitioners can provide proof of the ingestion of the medicine. However, in some cases this method can be impractical and not entirely accurate as patients can mimic the administration of the medicine only to discard it afterwards (Ting et al., 2020). Moreover, direct observations are possible only for hospitalised or institutionalised patients and are impractical to use in large population settings (Lam & Fresco, 2015). A study conducted by Ting et al. (2020) suggests the need for alternative treatment delivery methods that are more accommodating to patients than clinic-based DOT such as video DOT or partially self-administered treatment. The treatment methods delivered to patients should be considered on a case-by-case basis (Ting et al., 2020).

Patients who are not provided with reimbursements or subsidies to travel to the clinic or community centre for weekly visits, as required by the DOT programme, may incur the monetary and time-related costs of the journey (Tanimura et al., 2014). Consequences of the former leads to loss of

wages, or results in the loss of employment (Tanimura et al., 2014). The DOT burdens patients with financial and opportunity costs (McLaren et al., 2016; Ting et al., 2020).

Furthermore, using directly observed therapy raises concerns about the autonomy of the patient. There is a feeling of invasion of privacy because they are being watched as they take medication. This may lessen the patients' ability to maintain privacy about their health and could prevent them from completing TB treatment or seeking TB testing in the first place (Cremers et al., 2015). The visits to the clinic for TB treatment or from the health worker to the patient's home may increase the potential for fear of stigma associated with TB (Cremers et al., 2015; McLaren et al., 2016).

2.4.3 The Value of mHealth Adherence Technologies

Mobile health is a medical and public health practice supported by mobile devices such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices (Kay et al., 2011). In most recent years, the WHO has defined mHealth as a healthcare and public health service delivery supported by digital health tools on mobile devices (WHO, 2020). Worldwide, TB programmes and technical partners have initiated various electronic health (eHealth) and mHealth projects in support of and to improve TB treatment and prevention (WHO, 2010). While digital technologies are becoming important resources for the entire healthcare sector, mobile wireless technologies are particularly relevant, due to their user-friendliness, broad reach, cost-effectiveness, and popular public acceptance (Backes et al., 2021). The increase in the use of mobile phones across the world has led to substantial growth in health SMS-based technology. The SMS provides an easy, cheap, and accessible technology for mHealth that is accessible even in remote areas with limited resources (Saberi & Johnson, 2011).

Technologies that are adopted for monitoring medication adherence provide the opportunity for continuous tracking of individual medication adherence behaviour (Mason et al., 2022). Adherence interventions such as reminders, monitoring, and other digital health technology are used to support TB patients during care (Nezenega et al., 2020). Several studies (Elliott et al., 2020; Franklin et al., 2020) highlighted the need for long-term studies to evaluate the impact of interventions aimed at improving medication adherence. Longer studies will, however, require considerable effort to minimise participant attrition over these greater time frames.

In addition, adherence technologies also compile real-time patient dosing history. This refers to doses being recorded right after the patients engage with the technology (sending an SMS response or opening the pillbox). On the other hand, healthcare providers can access patient dose-taking patterns

on a web-based interface. This will enable them to identify non-adherence before the patient returns for their next medication refill visit (Subbaraman et al., 2018).

South African patients who have used digital intervention technologies for treatment adherence expressed a willingness to use the device during a full course of TB treatment (Andersen et al., 2016; Bionghi et al., 2018; Evans et al., 2016). A recent study by Mukora et al. (2023) on acceptability of using the medication monitor and experience of a differentiated care approach for TB treatment adherence among people living with TB in South Africa found positive attitude towards using the medication monitor. Qualitative studies (Bachman DeSilva et.al., 2013; Berry et al., 2019; Bionghi et al., 2018; Dworkin, Lee et al., 2019; Haberer et al., 2013; Vo et al., 2019; Woods et al., 2019) generally encountered positive feedback in relation to using mHealth devices. Patients felt empowered and engaged in their own healthcare. Receiving text reminders was appreciated because it helped patients to remember taking their medication as forgetting to do so is a common barrier to adherence.

A study conducted in Taiwan by Huang et al. (2017) on medication non-adherence caused by forgetting and delays, used personalised medication systems that send an SMS to the user to remind them to take their medication. Good results were observed in over 1 000 patients who forgot to take their medications, although only short-term medication adherence was investigated. Additional studies (Haberer et al., 2016; Ware et al., 2016) suggest that sending reminders, either in the form of text or audio-visually (ringing sound and glowing light), prompts patients about where medications are stored and promote a habit of pill-taking behaviour. Currently, the reminder systems are being implemented to improve patient adherence to tuberculosis clinic appointments for diagnosis and treatment.

More recent studies on mobile health instruments (Ahmad et al., 2020; Ali et al., 2019; Badawy et al., 2019; Carmody, 2019; Haase et al., 2017; Hincapie et al., 2019; Kjos et al., 2019; Morano et al., 2019; Morrissey et al., 2018; Xiong et al., 2018) measured the user acceptability of utilising mobile technologies and investigated the impact of the mHealth tools on medication adherence. Hincapie et al. (2019) highlighted the importance of considering diverse experiences when engaging patients in mHealth for medication adherence. Furthermore, better outcomes are reached when the user's individualised medication adherence strategies are used. Based on the different characteristics of each of the adherence technologies and the patient's individual situation, multiple options might be suitable.

Concerns highlighted relating to using mHealth technologies include digital exclusion, accessibility (connectivity and cost), privacy, confidentiality, personalisation, and fears that it might be used to replace other health services. Future studies need to investigate barriers to adoption and sustainability, for example, integration of technology into everyday life in the context of already established disease self-management routines (Sarradon-Eck et al., 2021; Dworkin, Panchal et al.,

2019; Bucci et al., 2019; Woods et al., 2019). It is furthermore important to conduct more research on mHealth adherence technologies to allay some of these concerns, especially from patients' personal perspectives. Health literacy is understood as "the ability of an individual to obtain and translate knowledge and information in order to maintain and improve health in a way that is appropriate to the individual and system contexts" (Liu et al, 2020, p.1). Therefore, health literacy can close the knowledge gaps that currently exist related to TB transmission, treatment, and prevention (Matakanye et al., 2021). When patients have a better understanding of the TB disease, their personal perspectives will be influenced by this information to less engage in risky behaviours. Meaning, they will utilise health services, seek diagnosis, and adhere to TB treatment.

2.5 THE RESEARCH GAPS

To achieve the End TB Strategy targets set for 2030 and 2035, it is important to prevent new TB infections and progression towards TB disease to reduce the burden of ill health and global mortality. TB treatment outcomes are improved with the use of adherence interventions such as patient education and counselling, incentives and enablers, psychological interventions, reminders and tracers, and digital health technologies (Alipanah et al., 2018). According to Lee et al. (2020), digital adherence technologies endorsed by the WHO as potentially important in supporting medication adherence have been increasingly implemented programmatically for TB. However, their application in TB research has been limited. Digital adherence technology interventions improve patient clinical outcomes as part of TB treatment adherence (Ngwatu et al., 2018), partially due to their communication component, which is responsible for detecting non-adherence events (SMS reminders).

Although several studies (Checchi et al., 2014; Demonceau et al., 2013; Evans et al., 2016; Haberer et al., 2016; Haberer et al., 2017; Pop-Eleches et al., 2011; Sabin et al., 2015; Vervloet et al., 2014) using mHealth technology have shown adherence efficacy, fewer studies, specifically as regards HIV research (Alipanah et al., 2018; de Bruin et al., 2017; Free et al., 2013; Linn et al., 2011; Liu et al., 2017) have evaluated whether these changes in adherence translate into better clinical outcomes such as improved viral suppression in patients with HIV. Limited studies with adequate sample sizes have reported on the accuracy and effectiveness of improving treatment outcomes and the usability of medication adherence systems (Aldeer et al., 2018; Subbaraman et al., 2018; Tomlinson et al., 2013). Although evidence remains minimal and generalisability limited, some of the studies reviewed suggested that the technologies that were utilised may be at least as effective as the standard of traditional care (Bionghi et al., 2018; Broomhead & Mars, 2012; Garfein et al., 2015; Ngwatu et al., 2018; Sinkou et al., 2017).

A systematic review conducted by Ngwatu et al. (2018) found evidence supporting the use of adherence technologies to limit TB. This finding is similar to HIV research conducted in relation to using mHealth technology. The authors suggest that more robust evidence is necessary for understanding how these technologies could impact patients and health care systems (Ngwatu et al., 2018). Subbaraman et al. (2018) support the previous authors, by positing that more research is essential to understand the impact of adherence technologies on patients and the health systems. Research is required to inform approaches to differentiated care, because little is known about the accuracy of adherence technologies in measuring adherence in patients with TB, especially with regard to larger-scale implementation in LMICs. Therefore, more robust data is required on adherence technologies to determine whether they have a positive impact on health outcomes, especially in high-TB burden LMICs (Subbaraman et al., 2018).

Limitations in the direct observed therapy strategy created a window of opportunity for additional supportive interventions aimed at increasing recognition of the successes in TB treatment. Alipanah et al. (2018) support the use of multiple interventions and future research to identify interventions that are most likely to improve adherence and outcomes, especially in resource-limited settings. As such, there is no "perfect" digital adherence technology that works optimally in every setting, especially high-income countries as compared to LMICs, or even for every patient in a single setting (Subbaraman et al., 2018). There is a need for researchers to suggest simpler, non-disruptive, accurate, and affordable methods, or a combination of methods, to monitor TB treatment adherence because many of the existing tools are not affordable in low-resource settings (Valencia et al., 2017).

It is important that research in adherence technologies focus on patient reminders and interactive approaches. For example, to look more creatively at how SMS can influence adherence behaviour other than by reminding patients to take their pills, by for example channelling cash transfers when milestones are achieved and combining SMS reminders with other digital solutions (Wald et al., 2015). In addition, Cele and Archary (2019) argue that mHealth studies that are based on an SMS reminder, which is sent as a daily or weekly reminder, need to determine the optimal frequency of these messages to support adherence.

Further research is necessary to generate more evidence-based knowledge of digital adherence use (mHealth) and adherence over time, specifically within the South African context, which is typified by a high-TB burden. Continuous data collection is preferred because this allows for the detection in changes in patterns over time, which may help to understand different stages in adherence to treatment (rather than a dichotomy prevailing) (Valencia et al., 2017). Digital adherence measures need to be acceptable by the patients and their social context, discreet and not disruptive of the patients' normal behaviour. Understanding user experiences is of key importance to resolve acceptability and

identifying programme-specific issues relating to the use of the technology over the short- and long term. In the end, it is essential continuously to monitor and evaluate patient-specific reasons for TB treatment non-adherence, with a focus on evaluating the knowledge deficits and their perceptions concerning TB disease. This information will assist with finding appropriate solutions to the low TB treatment success rate (Adisa et al., 2021).

Limited funding for public health and sustainable mHealth interventions is a major problem, especially in resource-limited countries with competing priorities (Kruk et al., 2017). Therefore, identifying interventions or support mechanisms that are most likely to improve adherence and outcomes, particularly in resource-limited settings, is crucial (Alipanah et al., 2018). After all, mHealth strategies are in line with the Fourth Industrial Revolution, as technology has become the focus (Cele & Archary, 2019) and advances in mobile technologies and applications are driving the transformation in health services delivery globally (Osei et al., 2021).

The highlighted gaps underscore the necessity for continuous monitoring and evaluation of patient-specific reasons for TB treatment non-adherence. Furthermore, evaluating the knowledge deficits of patients about TB, and their perceptions of the disease will also be essential in finding appropriate solutions to the low TB treatment success rate (Adisa et al., 2021) and help to develop new strategies to overcome the barriers and promote positive TB outcomes.

2.6 CONCLUSION

In this chapter, the burden of TB was reviewed in relation to the epidemic status, End TB Strategy, and the impact of the Covid-19 pandemic. Several barriers to medication adherence, the landscape of digital adherence technology and methods for measuring TB adherence were discussed. The value of mHealth adherence technologies and research gaps comprised the final part of this chapter. The theoretical framework of the present study is discussed comprehensively in the chapter that follows.

CHAPTER 3: THEORETICAL FRAMEWORK

This chapter gives an overview of five prominent health behaviour theories used to understand patient health behaviours in relation to promoting medication adherence. Thereafter, the health belief model, derived from the SCT, which informed the current research process and is used in the interpretation of the research findings, is dealt with.

3.1 HEALTH BEHAVIOUR THEORIES EMPLOYED TO PROMOTE MEDICATION ADHERENCE

Adherence to a medical regimen is a complex behavioural issue, especially relevant for long-term treatment in an outpatient setting where individual and environmental factors influence behaviour. Behavioural theories are thus needed to understand and conceptualise behaviour and behaviour change. Theories can also assist in the development of clear behaviour change interventions designed to improve medication adherence, and therefore, increasing transferability (Okuboyejo et al., 2018). While numerous theories are used in promoting adherence on various health behaviours, this section focuses briefly on describing some theories related to long-term adherence to TB treatment. The researcher will address the following five main theoretical perspectives, namely: (1) biomedical/biopsychosocial model; (2) behavioural; (3) communication; (4) self-regulation, and the (5) cognitive. The health belief model is a cognitive behavioural framework used to understand TB patient behaviour in the context of this study and it is derived from the SCT.

3.1.1 Biomedical/Biopsychosocial Perspective

According to this perspective, disease or health is related to biomedical causes and treatment is focused on the patient's physical health components. Patients are assumed to be passive recipients of the health provider's instructions (Ross & Deverell, 2004). This mechanistic view of illness requires mechanical solutions, such as prescribing pills to treat patients. In relation to medication non-adherence, this perspective does not ascribe it to the behaviour of the individual but it is understood to be caused by the patient's biological or genetic characteristics or their demographics such as age and gender (Blackwell, 1992). The limitation of this perspective is that it focuses on the biology alone and ignores other human factors that may have an impact on health behaviour, such as psychosocial influences, the impact of the soceconomic environment and the patient's perceptions of their own illness (Blackwell, 1992; WHO, 2003). Various theories have been developed in reaction to the biomedical theory to include the human element in health behaviour.

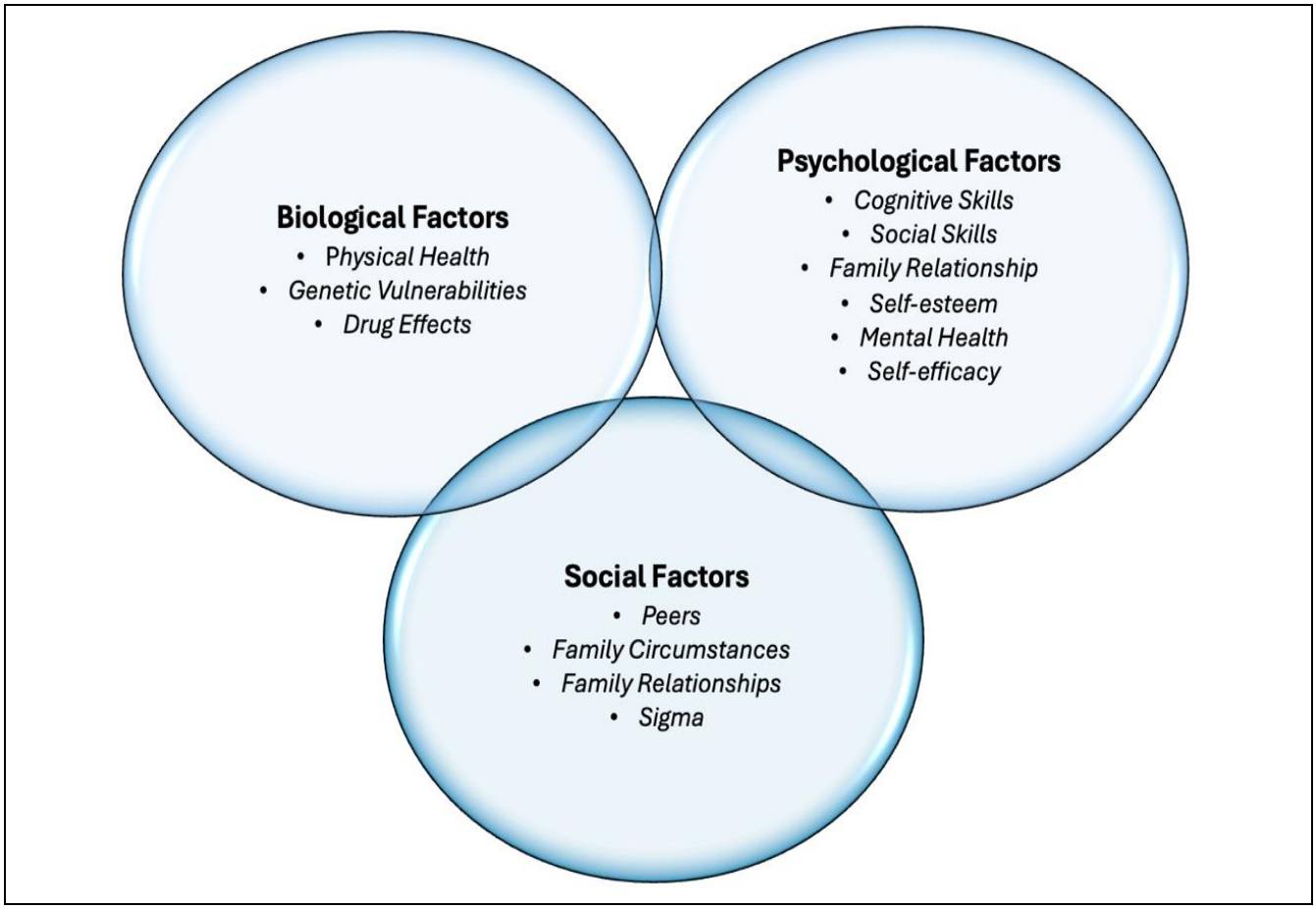
The biopsychosocial model, for example, recognises that social and psychological factors play a role in developing illnesses (Babalola et al., 2017; Karunamuni et al., 2020; Kusnanto et al., 2018;

Taukeni, 2019; Vinson et al., 2015). According to Engel (1977), as illustrated in Figure 7 (next page), this model illustrates the interaction of biological, psychological, and social factors in determining the health outcome.

The biopsychosocial model enables the ease with which health professionals better understand their patients' subjective view of their illness and suffering (Borrell-Carrió et al., 2004; Kusnanto et al., 2018). This model also allows for a more holistic approach to treatment. Critics of this model (Babalola et al., 2017; Gatchel & Oordt, 2012; Karunamuni et al., 2020; Kusnanto et al., 2018; Suls & Rothman, 2004) argue that adopting the biopsychosocial model for every single patient is a demanding task, that it is considered a luxury that many healthcare systems in resource-poor settings cannot afford, and that establishing a cause–effect relationship between biological, psychological, and social factors to influence the occurrence of the illness remains a complex undertaking. In the context of TB treatment, a study conducted by Vinson and colleagues (2015) on the biopsychosocial factors affecting the treatment outcomes of pulmonary tuberculosis among patients enrolled in TB DOTS clinics in the Philippines concluded the following: 1) psychosocial factors influence the success of the biomedical treatment of pulmonary tuberculosis; and 2) the odds ratios of pulmonary TB (PTB) treatment failure is significantly increased when the patient comes from a dysfunctional family. Therefore, the study recommends identifying and addressing the family psychosocial factors of treated TB patients to help achieve treatment success (Vinson et al., 2015).

Figure 7:

The Biopsychosocial Model



Source: The image was adapted from the paper entitled *The need for a new medical model: A challenge for biomedicine*, by Engel, 1977, (https://www.science.org/doi/10.1126/science.847460).

3.1.2 Behavioural (Learning) Perspective

The behavioural learning perspective is defined by principles of antecedents (internal thoughts or external environmental cues) and consequences (punishment or rewards) and their influence on behaviour (Skinner, 1974). The focus is on the environment and teaching skills to manage adherence; therefore, patients are likely to follow specific behaviours depending on these principles. Patient reminder strategies informed by this perspective have been found to improve adherence. However, further evidence is required to determine the effectiveness of strategies of this type (Munro et al., 2007; WHO, 2003). Patient reminders in this study were used as external cues for behaviour. If the patient did not open the box at a specified time, they would receive a reminder that would reinforce the action of opening the pill box and taking their medication. Essentially, the study measured the influence of mHealth feedback reminders on TB patients' medication adherence. The behavioural perspective does not consider fewer conscious influences on behaviour that are not linked to immediate rewards, such

as habits, lack of acceptance of a diagnosis, and past behaviour (Blackwell, 1992), and is mainly limited to external influences on behaviour (Munro et al., 2007).

3.1.3 Communication Perspective

Communication is the cornerstone of every patient–healthcare provider relationship; hence, improving this relationship may enhance adherence (Ross & Deverell, 2004; WHO, 2003). Medication adherence can be achieved through good healthcare provider communication skills and patient education (clear instructions on the timing of taking medication). Interventions designed to improve communication between the patient and the healthcare provider have shown improvements in patient satisfaction, with positive care and health outcomes (Ames et al., 1996; Munro et al., 2007). Du et al. (2020) explored the predictive role of treatment adherence, doctor–patient trust and communication in treatment effects between urban and rural TB patients. In their study, these researchers found that the urban patients reported better treatment effect compared to rural patients. The applied structural equation modelling found that the urban patients' treatment effect was only influenced by treatment adherence while the rural patients' treatment adherence was influenced by both treatment adherence and doctor–patient trust, which directly and positively predicted their treatment effects. In this case, doctor–patient communication positively influenced treatment adherence (Du et al., 2020). The use of an mHealth technology device is designed to enable the patients to set the timing for medication intake. In addition, whenever the device is not opened each day, a reminder SMS communication is sent to both the patient and the healthcare provider. Monitoring and evaluation are both important in improving adherence.

This perspective, according to Blackwell (1992), is critiqued for ignoring attitudinal, motivational, and interpersonal factors that may affect both the reception and translation of knowledge into behaviour. In addition, the perspective is restricted to the patient health provider interactions and ignores any social or financial support that may be required (Munro et al., 2007). In addition, cultural language factors are prominent in aspiring to sound communication.

3.1.4 Self-regulation Perspective

The self-regulation perspective is focused on individuals' subjective experience of health threats to understand the way they adapt to these threats (Munro et al., 2007). This perspective serves as a guideline to further understand patients' use of coping strategies to manage health threats that subsequently result in associated outcomes. In this case, people are viewed as active, self-regulating problem solvers, whose selection of coping strategies are informed by their personality, and social, and cultural context (Benyamini et al., 2004; Rachman, 1980). The overall benefit of interventions targeting self-regulatory mechanisms is not well-understood. Additional research is necessary to

advance the understanding of the efficacy of adherence interventions focused on self-regulation (Wilson et al., 2020). The use of an mHealth device supports patients' adherence management and their self-regulation to achieve the desired goal of completing TB treatment (Bosworth et al., 2018).

3.1.5 Cognitive Perspective

The cognitive perspective shares the assumption that attitudes, beliefs, expectations, and outcomes of future events are major determinants of health-related behaviour. This means, people choose actions that will lead mostly to positive outcomes (LaMorte, 2022; WHO, 2003). In this context, the researcher assumes that TB patients will choose to complete their treatment, as prescribed, to be cured. The highlighted weakness of this perspective, in relation to medication adherence, is that it does not adequately address behavioural skills required to ensure adherence. In addition, Munro et al. (2007) argues that other factors which may influence adherence behaviour (power relationships, social reputation and the possibility that risk behaviour may involve more than one person) are ignored.

The five main theoretical perspectives discussed are relevant to this research study because, first, TB disease is related to the biomedical causes, and treatment of TB involves the patient physically. Second, the patient's thoughts and understanding of the consequences of taking TB medication can influence whether they will be adherent or not. Third, patient–healthcare practitioner relationship and communication about the importance of taking TB treatment is central to improving medication adherence. Fourth, the patient's individual experiences, health threats and coping strategies are important to understand because they affect the associated TB outcomes we observe at the end of treatment. Last, the patient's health-related behaviour is assumed to be determined by attitudes, beliefs, expectations, and outcomes of future events. Aspects of all five theories can be integrated into the one health belief model to provide a holistic understanding of utilising an mHealth tool (wisepill device) to study the effect of the device's feedback reminders on TB patients' medication adherence.

The social cognitive theory is used as the main theoretical framework to guide this research and ultimately to explore and describe adherence behaviour. From the perspective of SCT, the study focused on the health belief model (HBM) to understand the phenomenon of adherence.

3.2 SOCIAL COGNITIVE THEORY

Developed by Albert Bandura, social cognitive theory suggests that human behaviour is a dynamic, reciprocal, and continuous interaction between the individual and the environment (Bandura, 1988). According to this theory, behaviour is learnt through interaction between internal factors such as thinking and symbolic processing (attention, memory, motivation) and external determinants (rewards and punishments) (Mimiaga et al., 2009). Therefore, health behaviour engagement is interactively

determined by personal characteristics, social interactions, and behavioural factors (Bandura, 2004). Core features of human behaviour include not only internal behavioural dispositions (cognition, affect or motivation), but also several environmental influences (social factors, physical factors, and health system-related factors) (Bandura, 2001).

The aim of social cognitive theory is to explain how individuals regulate their behaviour to achieve and maintain their goals over time. There are four processes of goal realisation, namely self-observation (observing of self to assess progress toward goal attainment and motivation towards behavioural changes), self-evaluation (comparing current performance with desired goal), self-reaction (individuals re-evaluation of goals in conjunction with their attainments) and self-efficacy (belief in the chances of goal achievement) (Bandura, 1989; van der Bijl & Shortridge-Baggett, 2002; Schunk, 2013). According to Redmond (2010), these mechanisms are not only interrelated, but they each have an influence on motivation and goal attainment. The constructs of the SCT are widely utilised and accepted (Bandura, 1998). Therefore, the SCT is very useful for studies focused on behaviour change in health promotion research (Islam et al., 2023).

Health promotion interventions that lack a thorough theoretical grounding and only focus on individual behavioural change contribute to the ineffectiveness of treatment outcomes (Stokols, 1996). On the basis of this theory, the study employed the HBM to determine the influence of mHealth feedback reminders on TB patients' medication adherence, and to understand, through end-user experiences, the barriers to adoption and sustainability of an mHealth tool. Jeihooni et al. (2016) argued that the SCT, together with the HBM, are effective models for health education and promotion. Both models are related to the pragmatism paradigm (see Chapter 4), because they demonstrate the complexity involved in medication adherence that requires practical solutions.

3.2.1 Health Belief Model

The health belief model was initially developed in the 1950s and was used in public health services by Hochbaum (1958), and Rosenstock (1960; 1974), to explain why people were failing to participate in programmes designed to prevent and detect disease. Later, the model was used to study people's responses to symptoms (Kirscht, 1974) and their behaviours because of being diagnosed with an illness, specifically adherence to medication regimens (Becker, 1974).

Essentially, the model explains that people will practise a particular health behaviour if they perceive a personal health threat and, second, whether they believe that engaging in certain behaviours or taking certain action will be effective for reducing that threat. In addition, the model consists of several primary concepts that predict why people will act to prevent, screen for, or control illness conditions. These concepts include susceptibility, seriousness, benefits and barriers to behaviour, cues

to action, and self-efficacy (Glanz et al., 2008). The study employed the health belief model to determine the influence of mHealth feedback reminders on TB patients' medication adherence, and also to gain an understanding, through investigating end-user experiences, the barriers to adoption and sustainability of an mHealth tool. A discussion of each construct is detailed below, followed by a summary captured in Table 2 to illustrate concepts and definitions of the health belief model. A summarised illustration of how these concepts fit together is presented later in the chapter (see Figure 8).

3.2.1.1 Perceived Susceptibility

Perceived susceptibility is a person's belief about how vulnerable they perceive themselves to be in relation to a particular health condition. It is further argued that when a person believes that they are at risk of a disease, illness, or negative health outcome; they are likely to do something to prevent it from happening. The opposite is true. When a person perceives low risk of getting a disease or condition, they tend to adopt behaviours that are less healthy (Arindari & Suswitha, 2020; Glanz et al., 2008).

3.2.1.2 Perceived Severity

Perceived severity is a person's feeling about the seriousness of contracting an illness or of leaving the illness untreated. Examples of severities include, but are not limited to, the inability to work, enduring the long-lasting effect of the disease, and becoming a burden to their family (Glanz et al., 2008). When perceptions of severity are heightened, people are more likely to act (Washburn, 2020). Personal susceptibility to a serious health condition results in perceived threat (Glanz et al., 2008) and willingness to respond to stay healthy.

3.2.1.3 Perceived Benefits

Perceived benefits refer to the person's opinion of the value or usefulness of available actions (new behaviour) in lowering the risk of disease. The belief that certain actions will lead to beneficial results makes people more likely to act. Change in behaviour alone, however, is not enough to cause change, even when people believe they are susceptible to the disease. In short, perceived barriers may outweigh perceived benefits (Glanz et al., 2008; Washburn, 2020).

3.2.1.4 Perceived Barriers

Perceived barriers refer to negative aspects of a particular health action, obstacles that stand in the way of behavioural change (Glanz et al., 2008). Barriers are regarded as both tangible (lack of financial resources and lack of transportation) and intangible (psychological such as fear, stigma, and

embarrassment). It is important to note that, if barriers are stronger than benefits, change will not occur. Hence, it is recommended in these instances that people be offered help to find ways to overcome barriers (Washburn, 2020).

3.2.1.5 Cues to Action

Cues to action are events, people, or things that trigger people to change behaviour (Washburn, 2020). For example, in the case where a patient is supposed to attend monthly scheduled visits at the clinic, cues such as calendar reminders can initiate an action (to attend their clinic on that scheduled date) (Glanz et al., 2008).

3.2.1.6 Self-efficacy

Self-efficacy is defined as "the conviction that one can successfully execute the behaviour required to produce the outcome" (Bandura & Walters, 1977, p. 193), as described earlier in this chapter. In essence, self-efficacy is the person's subjective judgement on whether they are capable of implementing certain actions to reach a particular outcome, for example, confidence in their abilities. High levels of self-efficacy are thus linked to a stronger commitment to change a behaviour or follow a treatment plan (Mobini et al., 2023).

Table 2:
Key Concepts and Definitions of the Health Belief Model

Outcome	Definition	Application
Perceived susceptibility	Belief about the chances of experiencing a risk or contracting a condition or disease	• Define population(s) at risk, risk levels • Personalise risk based on a person's characteristics or behaviour • Make perceived susceptibility more consistent with individual's actual risk
Perceived severity	Belief about how serious a condition and its sequelae are	• Specify consequences of risks and conditions
Perceived benefits	Belief in efficacy of the advised action to reduce risk or seriousness of impact	• Define action to take: how, where, when; clarify the positive effects to be expected
Perceived barriers	Belief about the tangible and psychological costs of the advised action	• Identify and reduce perceived barriers through reassurance, correction of misinformation, incentives, assistance
Cues to action	Strategies to activate "readiness"	• Provide how to information, promote awareness, use appropriate reminder systems
Self-efficacy	Confidence in ability to act	• Provide training and guidance in performing recommended action • Use progressive goal-setting • Give verbal reinforcement • Demonstrate desired behaviours • Reduce anxiety

Source: Glanz et al. (2008).

3.3 APPLICATION OF THE HEALTH BELIEF MODEL IN THE CONTEXT OF MEDICATION ADHERENCE

Medication adherence is a very personal experience influenced by many simultaneously interacting factors. Boukhechba et al. (2018) argue that a deeper contextual understanding is required in the development of interventions targeting non-adherence. It is also imperative to improve health self-management of patients with TB, because of the potential benefit of reducing drug resistance, improving the cure rate, and controlling the prevalence. Thus, mHealth interventions based on behavioural science theories may prove promising in the effort to achieve this goal (Bao et al., 2022). In this case, application of the HBM as a guiding framework for health behaviour intervention will help understand TB patients' medication adherence.

3.3.1 Perceived Susceptibility

There is a wide variation in people's feelings of personal vulnerability to an illness or disease (LaMorte, 2022). If patients believe that their chances of developing complications (drug resistance) from TB disease when not following their treatment, together with the notion that they may infect other people with TB, they may be more likely to take their medication. Studies conducted on HBM (Kamran et al., 2014; Wei et al., 2017; Venkatachalam et al., 2015) indicated that patients who perceived themselves to be more vulnerable demonstrated better adherence to medication. Furthermore, perceived susceptibility influences behavioural attitudes, which influence behavioural intentions (Pan et al., 2023).

3.3.2 Perceived Severity

There is a wide variation in the feelings of people regarding severity, and therefore they frequently consider the medical consequences (death, disability), and social consequences (family life, social relationships) when evaluating severity (LaMorte, 2022). TB patients, if they perceive that the consequences of leaving the disease untreated will potentially result in death, inability to go to work, becoming a burden to the family and suffering social isolation, might adhere to their treatment. According to Kamran et al. (2013), Ramli et al. (2012), and Venkatachalam et al. (2015), patients with hypertension who perceive a very high level of severity showed good adherence to medication. A study conducted by González-Castro et al. (2021) on perceived vulnerability and severity predicting adherence to COVID-19 protection measures found that individuals' perceived severity and vulnerability to COVID-19 was related to the use of more protective behaviours. It is important to note that the combination of susceptibility and severity has been labelled as perceived threat (Glanz et al., 2008).

3.3.3 Perceived Benefits

Patients are likely to accept the recommended health action if it is perceived as beneficial (LaMorte, 2022). According to Chauke et al. (2022), and Kasahun et al. (2022), patients' predetermined ideas and beliefs about medication and disease are powerful factors in following treatment regimens. For example, if TB patients believe that completing the treatment will cure their illness, they will be more motivated to take all their prescribed medication. Studies conducted with patients who perceived the treatment, medication-taking, for example, to be beneficial generally demonstrated better adherence (Joho, 2012; Kamran et al., 2013; Wei et al., 2017; Venkatachalam et al., 2015). In addition, the study by Pan et al. (2023) of factors influencing medication adherence in elderly patients with hypertension, found that perceived benefits had a direct positive effect on behavioural intentions and antihypertensive medication adherence behaviour.

3.3.4 Perceived Barriers

Perceived barriers to medication adherence among hypertensive patients, according to Washburn (2020), originates in the patient's pessimism about matters, which could potentially interrupt their medication-taking routine. For example, issues such as lack of efficacy, costs, forgetfulness, medication side effects, depression, that it is time-consuming, inconvenient, and is a complicated regimen when taking different drugs, can be barriers to adherence (LaMorte, 2022; Washburn, 2020; Woode et al., 2022). Conversely, perceived barriers can diminish individuals' recognition of the effectiveness and importance of medication therapy. This creates doubts and resistance to medication adherence (Sadeghi et al., 2022). There are wide variations in patients' perception of barriers, or impediments, which causes them to do a cost and/or benefit analysis (LaMorte, 2022). According to Venkatachalam et al., (2015), patients who perceive a strong barrier tend to exhibit significantly poor medication adherence. Moreover, Kamran et al. (2013) showed in their study that perceived barriers were the strongest factor in predicting medication non-adherence. In addition, Courtwright and Turner (2010), in their systematic review on the impact of TB stigma on TB diagnosis and treatment, found that TB stigma was perceived to increase TB diagnostic delay and treatment noncompliance, although attempts to quantify its impact produced mixed results.

3.3.5 Cues to Action

LaMorte (2022) defined cues to action as the stimulus necessary for triggering the decision-making process to accept a recommended health action. The relevant cues can be internal (chest pains, wheezing), or external (advice from others, reminders). Medication-taking is a behaviour that occurs in the context of other behaviours that can serve as a cue for action to initiate the behaviour of interest

(Bandura, 1986). For example, when a patient has a routine or schedule for taking medication, they are more likely to be adherent, even when the timing of medication intake happens during other behaviours (at work, when eating or travelling) (Bandura, 1986; Grunfeld et al., 2005; Wells et al., 2016). Furthermore, contextual cues play an important role in supporting medication adherence, as they aid both prospective memory and habit formation; as a result, medication-taking becomes a part of a daily routine (Stawarz et al., 2016). The wisepill device technology used in this study to support medication intake creates a schedule for the patient as the medication intake times (preferred by patients) are set beforehand. In addition, feedback reminders from the wisepill device are a conditioned process designed to influence TB patients' medication adherence. Reminders are helpful, especially in situations where patients experience several events at the same time or forget to take their medication multiple times (Boukhechba et al., 2018).

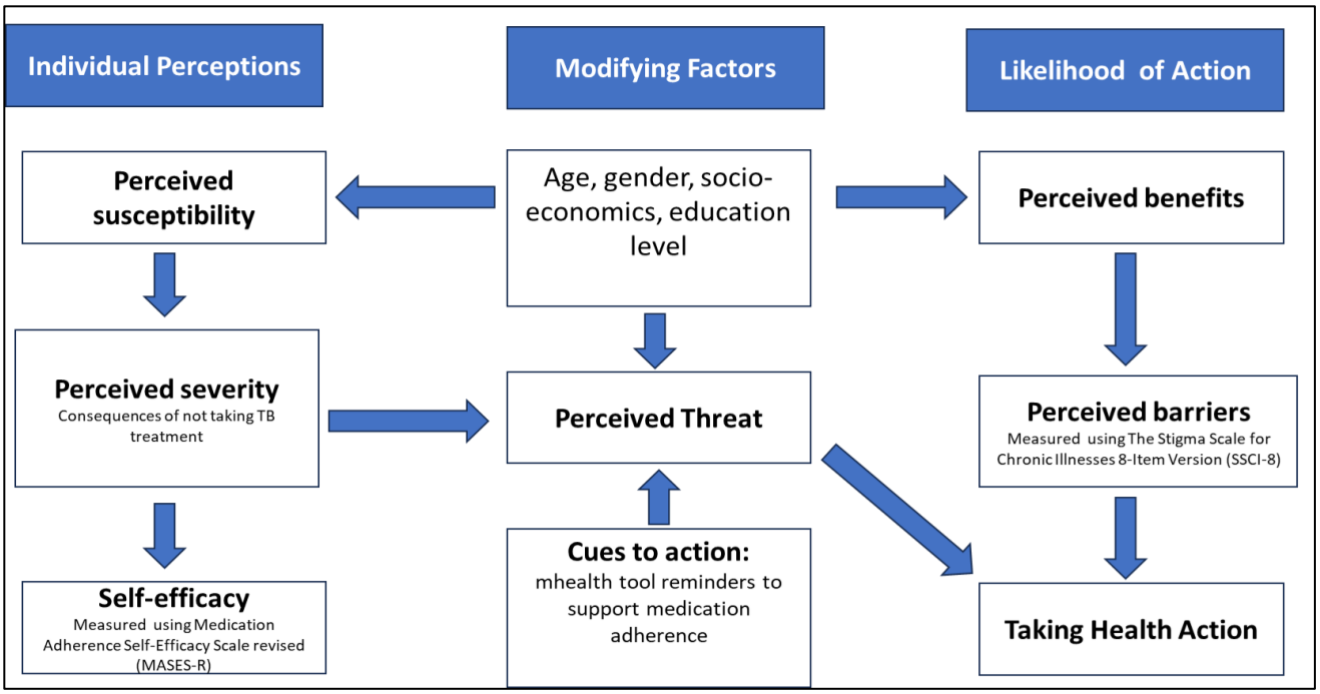
3.3.6 Self-efficacy

Self-efficacy is a construct in many behavioural theories that relates directly to whether a person performs the desired behaviour (LaMorte, 2022). A study conducted by Kara (2022) on general self-efficacy and hypertension treatment adherence in Algerian private clinical settings reported on a higher level of self-efficacy which was found to have a positive correlation with a higher level of treatment adherence. These findings illustrate that it is possible to increase the medication adherence of hypertension patients by enhancing their level of self-efficacy (Kara, 2022). In the context of TB patients, for example, if they believe that they can learn new behaviours (taking medication in the morning), they are more likely to succeed in doing so, even when faced with obstacles (Bandura, 2004). Furthermore, individuals who have self-belief and exercise control over their thoughts, feelings, and actions are likely to experience fewer health risks and to follow healthier lifestyles or make healthier choices (Clark & Dodge, 1999).

Other variables have been identified by Glanz et al. (2008) that indirectly influence health-related behaviour. These variables include diverse demographic, socio-psychological, and structural variables. For example, sociodemographic factors, particularly educational attainment, are believed to have an indirect effect on behaviour by influencing the perception of susceptibility, severity, benefits, and barriers (Glanz et al., 2008). Figure 8a (Glanz et al., 2008, p.49) illustrates how the concepts depicted in the HBM are linked in the context of this study.

Figure 8a:

Health Belief Model Concepts and Links



Source: Adapted from *Health behaviour and health education: Theory, research and practice* (4th ed., p.49), by K. Glanz et al, 2008, Wiley

3.4 LIMITATIONS OF USING THE HEALTH BELIEF MODEL

The health belief model has been used for over half a century to predict health-related behaviours and to frame interventions to change behaviours (Glanz et al., 2008). However, several limitations prevail when considering the model as a theory to predict health-related behaviours. These are limitations of the model's utility in public health. LaMorte (2022) listed the following limitations of the model, as captured in the bulleted list below:

- The model does not account for a person's attitudes, beliefs, or other individual determinants that dictate their acceptance of a healthy behaviour (LaMorte, 2022).
- The model does not consider behaviours that are habitual and may thus inform the decision-making process to accept a recommended action (smoking) (LaMorte, 2022).
- The model does not consider behaviours that are performed for non-health-related reasons, such as social acceptability (LaMorte, 2022).
- The model does not account for environmental or economic factors that may prohibit or promote the recommended action (LaMorte, 2022).

- The model assumes that everyone has access to equal amounts of information on illness or disease (LaMorte, 2022).

- The model assumes that cues to action are widely prevalent in encouraging people to act, and that "health" actions are the main goal in the decision-making process (LaMorte, 2022).

In addition, the researcher also highlighted limitations pertaining to the model in relation to the current study, which will be discussed.

3.4.1 Limitations of the Health Belief Model in the Context of the Study

Perceived susceptibility, severity, benefits, and barriers are some of the cognitive constructs that the HBM focus on to predict health behaviour (i.e. why people take actions to control their illnesses). The model does not, however, capture the emotional and social aspects that affect health behaviours. In the context of TB, socioeconomic related factors have been identified as key drivers that influence non-adherence behaviour. In essence, individuals do not make rational decisions based on weighing the advantages and disadvantages of health, but their health behaviours are also indirectly affected by the social and cultural factors on health beliefs.

The HBM makes assumptions that everyone has equal access to information regarding illness and disease – in reality, that is not the case. In the context of TB, there is still a lack of understanding among people about TB and this contributes to their false perceptions that TB is incurable and is highly contagious throughout treatment. In addition, people who are mostly affected by TB, who are socially disadvantaged (i.e., poor, socially marginalised population, among others) cannot benefit equally from HBM intervention. Furthermore, this disadvantaged group of individuals are also subjected to being stigmatised and discriminated against because they are viewed as a public health threat. This, in turn, may contribute to them not seeking healthcare services.

The HBM overemphasises individual responsibility for health and neglects other broader environmental and structural factors that influence health behaviours. In the context of TB, the disease has been linked with environmental risk factors that go hand-in-hand with poverty. This includes indoor air pollution, tobacco smoke, malnutrition, overcrowded living conditions, and excessive alcohol use (Schmidt, 2008). It is therefore important for the model to exercise flexibility that will account for changes in beliefs, attitudes, and behaviours over time in response to interventions. Now scientists are presenting convincing evidence to back these associations, leading some TB experts to argue that control programmes must confront underlying risk factors to limit the spread of the disease (Schmidt, 2008).

3.4.2 Key Lessons from the Health Belief Model

The health belief model is descriptive rather than explanatory and does not suggest a strategy for changing health-related actions. Individual constructs from the model are useful, although this depends on the health outcome of interest. Perceived susceptibility, benefits, and barriers have consistently been associated with the desired health behaviour. To maximise the effective use of the model, it should be integrated with other models that account for the environmental context and suggest strategies for change (LaMorte, 2022).

In light of the limitations from the health belief model, this study also used the social ecological model as it recognises that individuals are embedded within larger social systems that describes interactive characteristics of individuals and environments that underlie health outcomes (Sallis et al., 2008; Stokols, 1992). The socio ecological approach can be applied to the field of health because it addresses behaviors at multiple levels and is most effective in supporting behavior change.

3.4.3 Incorporating the Social Ecological Theory

Stokols (1992, 1996) argues that the social, physical, and cultural aspects of an environment have a collective effect on health. Therefore, creating sustainable health improvements targeting all of these factors (Sallis et al., 2008).

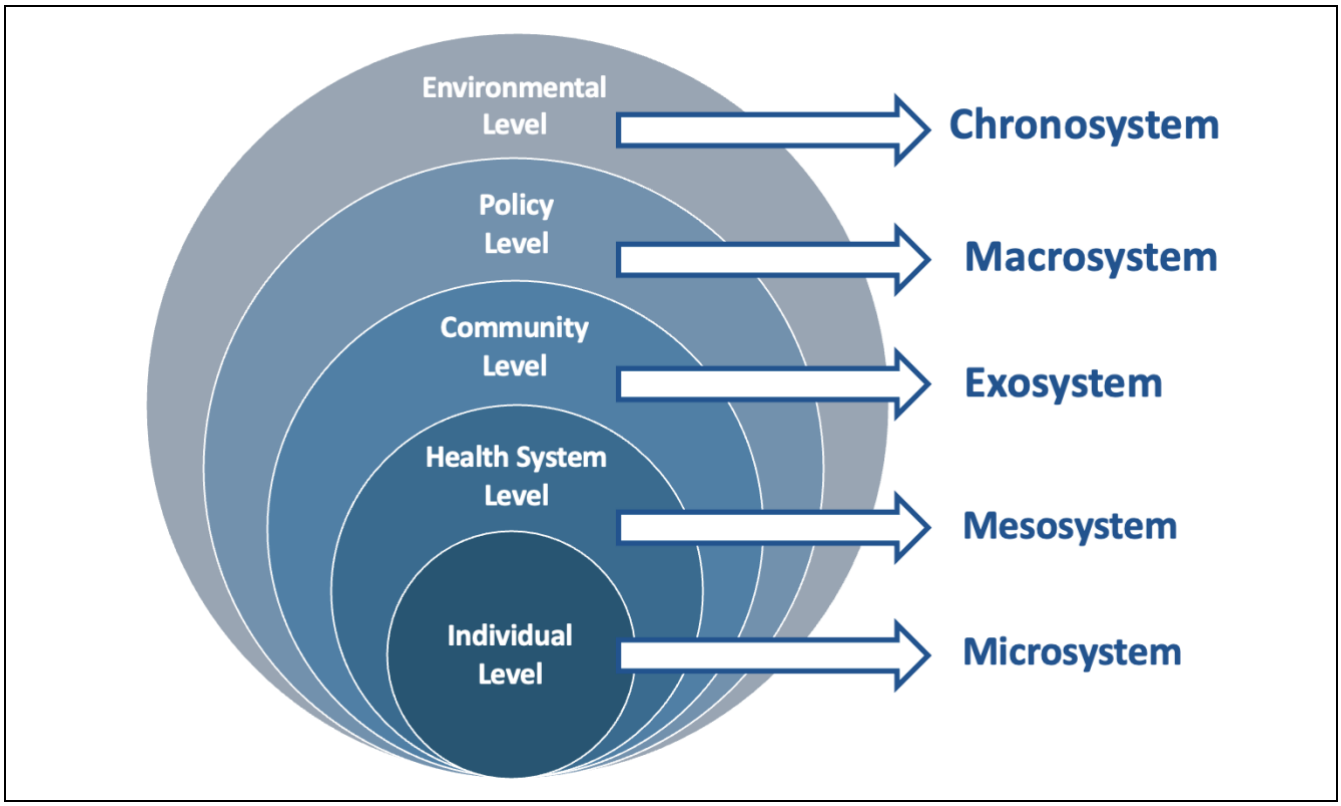
According to Bronfenbrenner (1995), behaviour takes place in a dynamic social context where the individual and social context are in constant interaction. Although Bronfenbrenner's theory was developed as a developmental theory focusing on children, this study will use it in the health context. In his Ecological Systems Theory, he identifies four ecological systems: the microsystem, the mesosystem, exosystem, and the macrosystem (Bronfenbrenner, 1979). The immediate environment or components of the person's behaviour (i.e., knowledge, attitudes, beliefs, and skills) is the microsystem. The relationship formed between two or more settings (i.e., person, health and treatment context) is the mesosystem. The exosystem is characterised by an environment in which the individual is not directly involved, but that impacts him/her anyway (i.e., external influences of friends, family, organisations, and community). The final ecological system is that of the macrosystem which consists of larger societal structures and values (i.e., social, cultural, political, religious) that does not only impact the life of an individual, but rather society as a whole. Bronfenbrenner in 1986 proposed an additional system called the chronosystem. This system examines the influence of environmental changes on an individual's development over time (i.e., marriage, death, divorce, chronic illness).

The social ecological model was applied to understand medication adherence in the TB context (Figure 8b). On an individual level (i.e. microsystem), multiple factors significantly affect TB treatment

adherence, such as lack of understanding of the disease, treatment related factors (i.e. side effects), socio-economic factors (i.e., unemployment, transport costs, and food insecurity), forgetfulness and negative attitudes - TB control efforts and adherenece can be enhanced through targeted education, support and improved communication (Matakanye & Tshitangano, 2024). The health system (i.e. mesosystem) for example include issues with clinic hours, long waiting times, and medicine availability. In addition, negative staff attitudes and a lack of DOTS supporters also hindered patient adherence (Matakanye & Tshitangano, 2024). The community level (i.e., exosystem) is characterised by the social and cultural context that has a significant influence on treatment adherence for TB patients. These levels encompass factors such as stigma, discrimination, and the impact of cultural, religious, and traditional beliefs on patients' willingness to adhere to TB treatment. On thepolicy level (i.e., macrosystem), policymakers need to address health system challenges to enhance adherence and reduce TB transmission rates (Matakanye & Tshitangano, 2024). Environmental level (i.e., chronosystem) factor such as having a chronic illness, for example TB patients co-infected with diabetes or hypertension and/ HIV find it challenging and overwhelming to manage multiple treatments. As a result, this can lead to potential non-compliance.

Figure 8b:

Application of the Social Ecological Theory in the context of medication adherence



3.5 CONCLUSION

A health behaviour theory-based approach to the study of medication adherence is critical as it promotes an understanding of patient health behaviours. The HBM helps to explain how a complex problem such as medication non-adherence requires feasible and workable solutions, in this case how an mHealth monitoring tool (as a cue to action) can support patients' behaviour change (adherence to medication intake). In addressing the limitations from the HBM, the social ecological model was used to account for the individual behaviour which is also shaped by the social and environmental context. Several important health theories were also discussed to contextualise the multifaceted nature of health behaviour such as medication adherence. In Chapter 4, the research methodology and collection of quantitative and qualitative data are presented.

CHAPTER 4: METHODOLOGY

In this chapter, the research methodology of the study is discussed. The chapter includes information about the paradigms in research, the aim, objectives, hypotheses, research design, and research methods of the study. The validity and reliability of the study are also summarised. The chapter concludes with a section dedicated to the data preparation and analysis, followed by the ethical principles adhered to in this study.

The researcher commenced with the debate between quantitative and qualitative paradigms in research, including the epistemological and ontological viewpoints. Pragmatism is discussed as the paradigm of choice as it reconciles different research methods.

4.1 QUANTITATIVE VERSUS QUALITATIVE PARADIGMS IN RESEARCH

For several decades, social sciences traditionally used quantitative methodologies to learn more about the world. This methodology is concerned with investigating factors that can be observed and measured in some way (Antwi & Hamza, 2015; Mohajan, 2020; Jilcha Sileyew, 2020). "Quantitative research was generally accepted as research paradigms in educational research until the early 1980s" (Antwi & Hamza, 2015, p.217). According to Schwandt (2001), a paradigm is a shared world view that is characterised by beliefs and values in a discipline that lends guidance to the way problems are solved. A dominant paradigm in quantitative research is positivism.

4.1.1 Positivism

Positivism as a philosophical stance on science that is the oldest and most widely used paradigm, originated in the nineteenth century when it was founded by a French philosopher called Auguste Comte (Chilisa & Kawulich, 2012; Neuman, 2014). Positivism is aligned with the hypothetico-deductive model of science, which is defined as:

> … a circular process that begins with theory from the literature to (1) build testable hypotheses, (2) design an experiment through operationalising variables (i.e., identifying variables to manipulate and measure through group assignments), and (3) conduct an empirical study based on experimentation. Ultimate findings from such a study are used to help inform theory and contribute to the literature, thereby completing the circular process (theory → hypothesis → operationalising variables → experimentation → theory) (Park et al., 2020, p. 690).

A positivist paradigm proposes that scientific methods are the only means to establish truth, objective reality, and true knowledge (Chilisa & Kawulich, 2012; Comte,1974; Neuman, 2014).

Researchers therefore operate in a dualistic and objective world, where the researcher does not interact with study participants to minimise bias (Park et al., 2020).

Ontology and Epistemology

The positivist paradigm assumes that reality is objectively given and is measurable using properties that are independent of the researcher and research instruments. This means that knowledge is objective and quantifiable. Ontology refers to the views and/or nature of reality, what exists and how we view reality (Hudson & Ozanne, 1988). According to Alharahsheh and Pius (2020), ontology is concerned with the phenomenon in respect of the nature of its existence. Furthermore, it seeks an answer to or the reality of a research question using existing knowledge. Epistemology refers to how knowledge is created, and how it is possible to know reality (Carson et al., 2001). Furthermore, "epistemology is considered as an internal factor within the researcher as it is also concerned with how a researcher can distinguish between right and wrong, and it is about how a researcher is viewing the world around them" (Alharahsheh and Pius, 2020, p.40). For positivists, the methodology adopted is mostly experimental, with the focus on hypothesis-testing; therefore, finding the cause-and-effect relationship between variables. Uncovering the truth and presenting it by empirical means is of key relevance to this paradigm (Henning et al., 2004).

4.1.2 Interpretivism

One example of an anti-positivist paradigm is interpretivism. This is an approach to qualitative research that focuses on observation and interpretation. Information about an event is collected through observation while, thereafter, the information is interpreted to make meaning of it. The latter is done by drawing inferences or by judging the match between the information and some abstract pattern (Aikenhead, 1997; Alharahsheh & Pius, 2020). In essence, the idea is to attempt to understand phenomena through meanings that people assign to them (Deetz, 1996), and to consider differences such as cultures, circumstances as well as times that contribute to the development of different social realities (Alharahsheh & Pius, 2020). The interpretivist paradigm stresses the need to put analysis in context (Reeves & Hedberg, 2003). Interpretivism, according to Alharahsheh and Pius (2020):

> … is more concerned with in-depth variables and factors related to a context, it considers humans as different from physical phenomena as they create further depth in meanings with the assumption that human beings cannot be explored in a similar way to physical phenomena (Alharahsheh & Pius, 2020, p. 41).

This approach does not predefine dependent and independent variables but focuses on the full complexity of human sense-making as the situation emerges (Kaplan & Maxwell, 1994).

Ontology and Epistemology

Interpretive researchers may adopt an intersubjective epistemology and the ontological belief that reality is socially constructed, which is driven by their belief that reality consists of people's subjective experiences of the external world. The interest of interpretivists is not in generating a new theory, but to judge or evaluate and refine interpretive theories. According to Myers (2009), access to reality (whether given or socially constructed) is only through social constructions, such as language, consciousness, and shared meanings. There is no objective knowledge that is independent of human reasoning. Therefore, the interpretive approach explains the subjective reasons and meanings that lie behind social action (Gephart, 1999). The approach links with qualitative research, which is concerned, among others, with gaining an understanding of individuals' social reality.

The paradigm wars between positivists and interpretivists peaked in the early 1980s. Many purists among quantitative and qualitative researchers argued that their approach was superior (Guba, 1990; Tashakkori & Teddlie, 1998). The positivists believed in the objective, law-like properties of a physical reality independent of observation (Donaldson, 1992; Wicks & Freeman, 1998), whereas anti-positivists placed emphasis on the creative role of active, subjective individuals. However, none of these two paradigms owns a privileged claim on truth (Astley, 2019; Burrell & Morgan, 2017; 2019; Martin, 2019). As a result, post-positivism was established to form the pluralistic approach that balances both modes of research inquiry (DeLuca et al., 2008; Kock et al., 2008). The researcher is of the view that, in order to address real-life problems, there is a need to take a practical approach, meaning to draw from the strengths and principles that guide each paradigm respectively. For example, in the context of tuberculosis, if we are to understand the issue of non-adherence to medication which has detrimental health outcomes that affect the patients, the national TB programme and the global community at large, we will therefore need to quantify the issue of non-adherence through monitoring and also to obtain explanations from end-users for a holistic understanding of the phenomenon. All of this can be obtained by adopting the pluralistic approach. In essence, both approaches are relevant to help solve the problem of non-adherence to TB study medication.

4.2 POST-POSITIVISM

The post-positivist paradigm promotes the triangulation of qualitative and quantitative methods since these methods explore the diversity of facts researchable through various kinds of investigations, but respecting and valuing all findings as important components of knowledge (Clark, 1998; Fischer, 1998). Post-positivism does not aim to disprove positivism, but instead places emphasis on the proper understanding of directions and perspectives of any research study in multiple dimensions and through multiple methods (Guba, 1990; Fischer, 1998). Therefore, pragmatism is a type of post-positivist

paradigm that offers a flexible and more reflective approach when combining both positivism and interpretivism in a single research project, given the nature of the research question (Feilzer, 2010; Morgan, 2007; Pansiri, 2005). The pragmatist epistemology stands in contrast to the two opposite philosophical orientations of the nature of reality, namely positivism and anti-positivism (interpretivism). Pragmatism fits in between the two extremes by stating that there is a "real world" out there, but at the same time all individuals have their own unique interpretations of that world (Morgan, 2007).

Pragmatism is assumed by the researcher to reconcile the two research methods. The pragmatist paradigm supports the nature of the study design (mixed methods) to answer the research questions.

4.3 PRAGMATISM

Pragmatism originated from the work of William James (1842–1910), John Dewey (1859–1952), Charles Sanders Peirce (1839–1914), and Herbert Mead (1863–1931). The pragmatist researcher is concerned with finding what works to enable solutions to problems (Creswell, 2003; Patton, 1990), in other words, searching for feasible, workable solutions to complex human problems (Fishman, 1999). For pragmatists, the questions about the laws of nature and reality (ontology) and theory of knowledge (epistemology) are not important, since the central focus is on the research question or problem (Creswell & Plano-Clark, 2011; Guetterman & Fetters, 2018; Mackenzie & Knipe, 2006). Powell (2001) indicated that, for pragmatism, the mandate of science is not to find truth or reality, which are perpetually in dispute, but to facilitate human problem-solving (Rorty, 1989; Stich, 1990). An advantage of a pragmatic approach is employing an "abductive" reasoning process, which moves back and forth between an inductive and a deductive reasoning process (Morgan, 2007). This abduction process is defined as a "retroductive process, in which where the researcher spontaneously makes inferences from instinctive reason to find or form hypotheses or theories that might explain a surprising fact or an unexpected observation" (Patokorpi, 2006, p. 73). Although pragmatism is related to post-positivist assumptions of the belief to describe an objective reality while looking from the "outside", the researcher acknowledges that it is not possible to be completely objective despite its practicality (Wagner et al., 2012).

Pragmatism and Mixed-methods Research

Pragmatism is a paradigm that is often associated with mixed-methods research designs (Biesta, 2021; Creswell & Plano-Clark, 2011; Johnson & Onwuegbuzie, 2004; Maxcy, 2003; Morgan, 2014; Teddlie & Tashakkori, 2003). The focus is on using the research methods that best answer the research question. However, the accuracy of using each research method is important (Creswell &

Plano-Clark, 2011). A mixed-methods approach provides a comprehensive understanding of the phenomena investigated, in this case health behaviour in the context of TB medication adherence. This is conducted by "employing participant-centred, culturally grounded set of techniques which methodologically integrate rigorous quantitative and qualitative approaches" (Guetterman & Fetters, 2018, p. 218). The researcher used questionnaires and interviews to collect data for this study. Statistical analysis and thematic analysis were conducted to answer the study's research questions (Creswell, 2003; Mackenzie & Knipe, 2006). The mixed-methods approach has been documented as effective for investigating complex health research conditions (Allana & Clark, 2018; Chiang et al., 2015). Researchers operating from the pragmatist paradigm are recommended to accept external reality and to choose explanations that best produce the desired outcomes (Pansiri, 2005).

4.4 JUSTIFICATION, AIM AND OBJECTIVES OF THE CURRENT RESEARCH

The motivation behind the current research was to investigate the behavioural change component emanating from mHealth use (Petit & Cambon, 2016) by measuring the influence of mHealth use on patients' motivation to complete treatment, given their perception of stigma and self-efficacy. Understanding perceptions of a chronic illness is important because it reflects the patient's role in exercising personal agency to improve their health outcome (Adams, 2010; Hibbard & Greene, 2013). In this study's context, the wisepill device (adherence measurement tool) was used to explain TB patients' medication use. This is partially due to the device's communication component (SMS reminders) (Ngwatu et al., 2018). The wisepill device indirectly reflects TB patients' medication adherence behaviour and their motivation to complete treatment. Furthermore, understanding patients' knowledge about TB, and their perceptions concerning the disease is also essential for finding appropriate solutions to the low TB treatment success rate observed in many developed and some developing countries (Adisa et al., 2021). Current evidence proposes the focus to be on understanding the connection between patients' experience, adherence, and health outcomes (Hamine et al., 2015) as the applicable technologies have not yet been fully explored (Nieuwlaat, 2014; Muessig et al., 2017).

Improving adherence thus requires an active process of behavioural change, education, motivation, tools, support, monitoring and evaluation (Alipanah et al., 2018; Kleinsinger, 2018; Izudi et al., 2019; Nieuwlaat et al., 2014). Therefore, the study seeks to generate more evidence-based knowledge of the value of mHealth use and adherence over time, specifically within the South African context. Generated evidence can be used by policymakers in defining the national standard for TB adherence. This could have a strong impact in public health to reduce transmission of the disease and inform the development of the treatment cascade, from testing to treatment completion and cure.

To address the gap identified in the research, the main aim of this study was to determine the influence of mHealth feedback reminders on TB patients' medication adherence. The TB patients' perceptions of self-efficacy and stigma were utilised to predict successful treatment outcomes to demonstrate medication adherence. In addition, a secondary aim intended to understand, through TB patients' experiences, the barriers to adoption and sustainable use of mHealth technologies.

4.4.1 The Study's Objectives are Presented in Summary as Follows:

- To measure medication adherence and feedback reminders using wisepill technology.
- To measure medication adherence by patient self-reports and using a three-item adherence scale.
- To compare scores from wisepill technology with other subjective scores (i.e., completed medication in each month, missed doses in each month and a three-item adherence scale).
- To measure the predictive ability of adherence scores from wisepill technology on TB treatment outcomes.
- To determine whether stigma and self-efficacy will predict adherence behaviour (i.e. TB medication adherence) even when reminders from wisepill technology are added.
- To explore end-user experiences with mHealth technology.

4.4.2 The Study's Hypotheses are Presented as Follows.

Hypothesis 1: On supportive feedback (reminders) from wisepill technology and adherence over time.

H_1: Supportive feedback (reminders) from wisepill technology will increase adherence over time.

H_0: Supportive feedback (reminders) from wisepill technology will not increase adherence over time.

Hypothesis 2: Wisepill technology scores versus subjective scores.

H_1: Wisepill technology scores and other subjective scores (completed medication in each month, missed doses in each month and a three-item adherence scale) will differ.

H_0: Wisepill technology scores and other subjective scores (completed medication in each month, missed doses in each month and a three-item adherence scale) will not differ.

Hypothesis 3: Adherence scores from wisepill technology is a predictor for TB treatment outcomes.

H_1: Adherence scores from wisepill technology will predict TB treatment outcomes.

H_0: Adherence scores from wisepill technology will not predict TB treatment outcomes.

Hypothesis 4: Stigma and self-efficacy as predictors of adherent behaviour.

H_1: Stigma and self-efficacy will predict adherence behaviour (TB medication adherence) even if reminders from wisepill technology are added.

H_0: Stigma and self-efficacy will not predict adherence behaviour (TB medication adherence) even if reminders from wisepill technology are added.

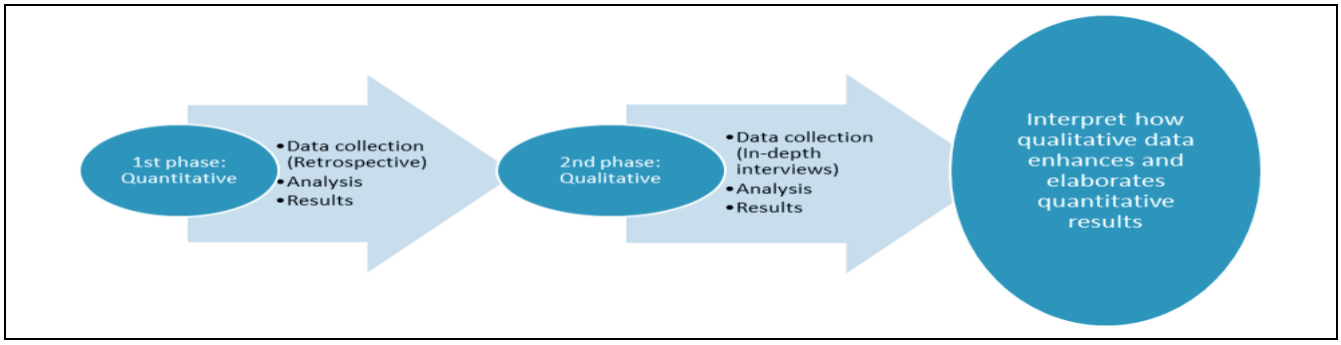
4.5 RESEARCH DESIGN AND MODE OF INQUIRY

4.5.1 Design

In this study, a mixed-methods research approach was used throughout the research process to integrate both qualitative and quantitative methods (Creswell, 2015). Specifically, a sequential explanatory design was used that prioritises both methods equally. In such a design, collection, and analysis of two independent strands of data, the quantitative (wisepill, three-item adherence scale, psychological measures, and pill count), and the qualitative (end-user experiences of using an mHealth tool) occurred sequentially, at different points in time through a quantitative phase, followed by a qualitative phase. The purpose was to use the qualitative results to supplement the interpretation of the findings from the quantitative phase (Creswell & Creswell, 2017) (see Figure 9).

Figure 9:

Two Phases of Sequential Explanatory Mixed-method Data Collection Design



The study used retrospective data collected on the usability of an mHealth tool to support medication adherence schedules in newly diagnosed TB patients. One group of patients were used that received the mHealth tool to support their medication adherence. Consequently, the study excluded the use of a comparison or control group because the idea was to understand the usability of the mHealth technology in supporting medication adherence among TB patients in a natural setting (measuring what it is designed for). Quantitative data were collected at three events, while qualitative data were only collected in the post-study period. Figure 10 contains a summary of the time sequence of data collection and assessments that were conducted (instruments used) at each event. (see section 4.4).

Figure 10:

Illustration of the Study Events and Time Sequence of Assessments

4.5.2 Rationale for Using Mixed-methods Research

The study explored medication adherence from a health psychology perspective. Using a mixed-methods approach enabled the researcher to explore health behaviour from both a quantitative and a qualitative perspective, thereby providing a more comprehensive understanding of medication adherence in the context of TB. Mixed-methods research involves "a participant-centered, culturally grounded set of techniques that employ, together, methodologically rigorous quantitative and qualitative approaches in an integrated, theory driven manner" (Guetterman & Fetters, 2018. p. 218). Quantitative (objectivity, numbers, and generalisability) and qualitative (rich description of participants' experiences) methods of data collection provide different types of information. The advantage of using a mixed-methods approach is that the complementary relationship between quantitative and qualitative data minimises the weaknesses associated with both methods when taken on their own.

Quantitative findings are supplemented and enhanced by the qualitative findings (Creswell, 2014; Creswell & Plano-Clark, 2017; Santos et al., 2017). Mixed-methods research provides more complementary and comprehensive evidence for studying a research problem by employing rigorous quantitative research (assessing magnitude and frequency of constructs) and in-depth qualitative research, which explores the meaning and understanding of constructs (Creswell & Plano-Clark, 2017; Denzin & Lincoln, 2011; Guetterman & Fetters, 2018). In relation to the current study, for example, the quantitative data can inform the researcher about the patients who were adherent or non-adherent

to TB treatment, although it cannot provide an understanding of their reasons to adhere or not to adhere to treatment. This was explored through a qualitative approach aiming to capture the personal experiences of patients regarding their TB adherence.

The disadvantage of using mixed-methods research is that the sample may be small which, in turn, may affect the generalisability of findings to larger representative and/or random samples. Despite the advantages associated with mixed-methods research, the method is complex to carry out because it is resource intensive (time-consuming and expensive). In the end, findings from this study can nevertheless contribute to elucidating the value of an mHealth tool to support medication adherence schedules among TB patients.

4.5.3 Sampling Selection Used in the Study

The Aurum Institute previously conducted a TB clinical trial project using the same mHealth support device (wisepill) at several local clinics located in Ekurhuleni. Several clinics were involved in selecting patients for the current study. The selection of clinic facilities in the Ekurhuleni district was based on convenience, the availability of TB initiation patients, patient follow-up, infrastructure for research on TB burden, and free treatment services. The Aurum Institute collaborated with the researcher and assisted with the sampling process. The institute donated the mHealth devices, facilitated the application for district approval, and introduced the researcher to the selected six study sites at Ekurhuleni from which the sample was recruited. Three study sites were classified as community healthcare centres (CHC), while the other three were clinics. By definition, a CHC is a facility that normally provides primary healthcare services, 24-hour maternity, accident and emergency services and beds where healthcare users can be observed for a maximum of 48 hours, and normally has a procedure room but not an operating theatre. In contrast, a clinic facility provides a range of primary healthcare services and is normally open eight or more hours a day based on the need of the community to be served (KwaZulu-Natal Department of Health, 2001). According to the South African TB management guideline published in 2014, patients with TB are expected to have conversion (i.e., after starting treatment sputum culture becomes negative) at two months of treatment to show effectiveness of the TB treatment; however, Baloyi and Manyisa (2022) reported that for Ekurhuleni district, non-conversion at two and three months of TB treatment is still high among some patients attending primary healthcare facilities. Therefore, this poses a challenge in TB management control (Baloyi & Manyisa, 2022). Unwillingness to take treatment for six months is one of several reasons recognised as contributing to patients with TB non-conversion (Baloyi & Manyisa, 2022).

This study aimed to recruit patients who were newly diagnosed with TB, initiated on standard TB treatment at six health facilities in the Ekurhuleni district, who were willing to use wisepill technology to support their medication adherence schedules.

4.5.4 Sampling Procedure

The researcher employed purposeful sampling to select participants deliberately who had qualities of interest and were best suited to answering the research questions (Becker et al., 2012; Bernard, 2002; Lewis & Sheppard, 2006). Although purposive sampling is easy and convenient compared to other types of sampling, the limitation comes with findings not being generalisable, especially when a small sample is used. In addition, selection was also based on convenience determined by whether the patient was easily accessible to the researcher in terms of geographical location. Patients who met the selection criteria were initially recruited by a registered nurse at the facility, who informed them about the study conducted on medication adherence. The facility-registered nurse was briefed by the researcher on the following exclusion/inclusion criteria for recruitment of patients:

4.5.4.1 Criteria for Inclusion in the Study

- Adults 18 years or older who were HIV-negative (the inclusion of HIV-positive patients would have had cost implications for the PhD study. In addition, the nature of the study is psychological – hence, the focus was on measuring psychological constructs).
- Newly diagnosed drug-sensitive (DS) TB patients (diagnosed at the clinics).
- Diagnosis of DS-TB (pulmonary TB).
- TB was diagnosed and multidrug-resistant (MDR) and extensively drug-resistant (XDR) TB was ruled out by the facility-registered nurse (the study did not directly collect this information but requested the facility-registered nurse to use this information as part of the selection criteria during recruitment).
- Newly diagnosed DS-TB patients who were initiated on standard TB treatment at the clinics (based on Xpert ®MTB/RIF results and rifampicin resistance pattern for current TB episode, smear test results, culture test results, Chest X-ray results, if available).
- Patients who were willing to be interviewed in-person and in English (multiple languages were nevertheless used to explain difficult concepts).
- Having access to a cell phone, able to use the cell phone or have someone (friend, family member, etc.) who could respond on their behalf.
- Willingness to learn to use and manage mHealth technology (study sent an SMS message to participants to read), and this practical demonstration was used to determine English proficiency (ability to communicate meaning verbally in English) and cell phone usage (readability of SMS).

4.5.4.2 Exclusion Criteria of the Study

- Patients younger than 18 years of age.

- HIV-positive patients.
- Patients unable to provide informed consent.
- Patients not initiated on DS-TB treatment.
- Patients not going to visit one of the study facilities in the district during normal working hours.
- Patients who have any form of drug-resistant tuberculosis (DR-TB).

The quantitative sample of the study consisted of 90 adult patients diagnosed with TB, who were purposively and conveniently selected. The 90 patients were enrolled from the approved study (HUM009/0420) between February 2022 and March 2023 and followed up for six months at health facilities in the Ekurhuleni district (see Appendices 2 and 3). The sample size was estimated at the prevalence of a successful TB treatment outcome of 70%–90%, with a margin of error of 5%. Thus, a sample of 80 to 100 was required. To estimate an odds ratio of 2.0 for an increase of 1 SD in the wisepill pill count, with 85% power, assuming successful TB treatment in 50%– 80% of patients, a sample of between 80 and 100 was adequate. A sample of 90 patients was therefore sufficient to achieve the objectives of the current study.

For the qualitative aspect of the study, a small sample of 10 participants was selected from those who were regarded as adherent and not adherent. There were six adherent and four non-adherent participants. The decision whether a participant was adherent or not was calculated by the researcher at the end of treatment (upon receiving treatment outcomes). The adherence data (the dose percentage) were calculated by means of the wisepill technology's SENSE software. In the context of the study, being adherent meant that patients would have taken at least 80%–90% of their prescribed doses. Percentages were computed by dividing the recorded number of days the pill box was opened (intake) divided by the total number of days in a month multiplied by 100. If the box is not opened, it is recorded as missed. A list was then drawn up of those who were adherent (patients who took at least 80%–90% of prescribed doses) and those who were not adherent (patients who took less than 80% of prescribed doses). The researcher then called the potential participants as they appeared in the drawn-up list to request their participation in the interview. The drawn-up list was an added criterion used by the researcher to select the 10 participants, purposively and conveniently.

It is important to note that most eligible participants from the list did not agree to participate as they were not available to come to the clinic (i.e. owing to work commitments, transferred out of the district), and others declined for personal reasons. Therefore, a meeting was scheduled with those who agreed (and signed a consent form) to participate and be interviewed for this study. The interviews took place at the facility where the participants received treatment to explore how they experienced the reminders through using the wisepill technology as having affected their behaviour.

4.6 METHODS AND MATERIALS

The researcher relied on a questionnaire to gather sociodemographic information and adherence self-reporting. The evriMED wisepill technology was used to record the regularity with which a medicine container was opened by the patient. The self-efficacy and stigma scales were used to measure stigma and self-efficacy, and the three-item adherence scale was also administered by the researcher. Pill count information was obtained from the facility-registered nurse and TB outcomes were obtained from the electronic tuberculosis register (ETR.web.net), also contained in the patient files. Both pill counts and overall TB treatment outcomes were captured in the questionnaire. For qualitative interviews, an interview guide was used to obtain in-depth information on participants' experiences of using the evriMED wisepill support technology. More detail about the data collection process is outlined in the data collection procedure (see section 4.7).

4.6.1 Quantitative Research Method

4.6.1.1 Biographical Questionnaire

The researcher compiled a structured biographical questionnaire (see Appendix 4) to collect sociodemographic information (gender, age, household characteristics, education level and employment status), the diagnosis date and treatment start date (see Appendix 4). In addition, the patient's self-reporting of adherence was (repeatedly) collected through this questionnaire at follow-up visits. The research team administered and patients completed the questionnaire during the first consultation.

The researcher and the research assistants piloted the questionnaire administration and procedures at one of the selected clinic facilities. This was done practically by enrolling the patient with the help of the registered facility nurse, obtaining consent, administering the questionnaire and psychological scales and training the patient to use the wisepill technology. It was important for patients to interpret the questions correctly and to provide relevant responses.

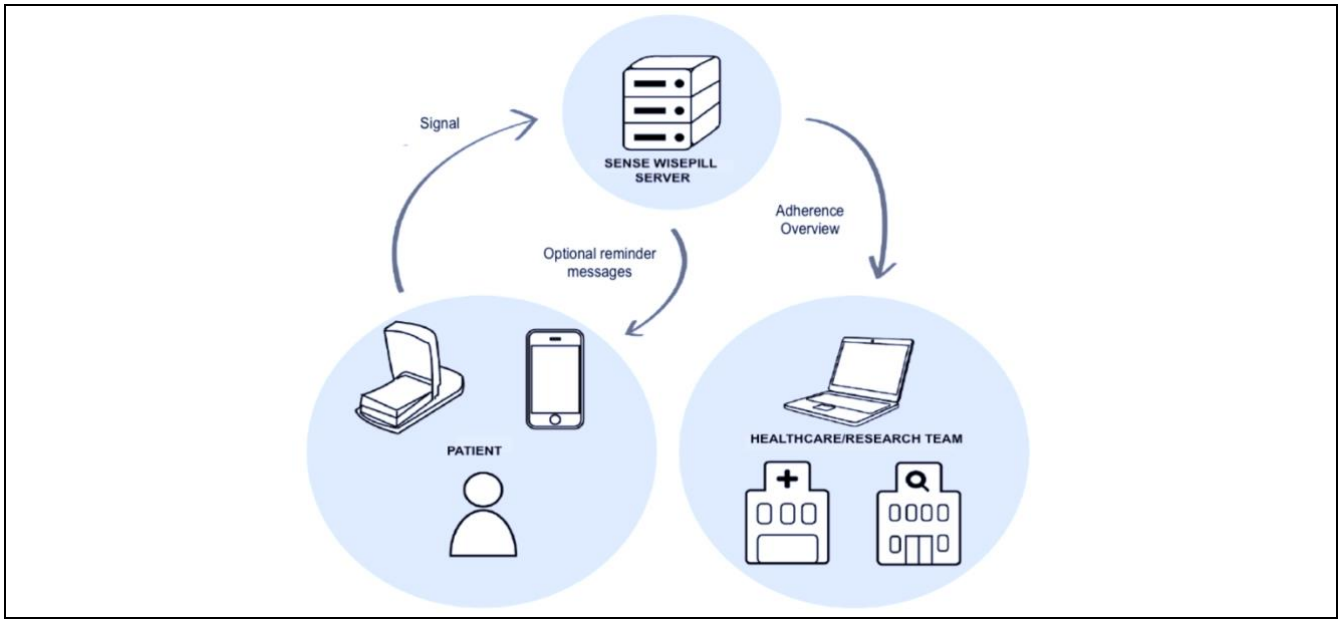
4.6.1.2 EvriMED Wisepill Box

The evriMED wisepill box (mHealth support technology used) is an automated electronic device that records and informs the healthcare provider about the regularity with which a medicine container is opened by the patient (assuming in most cases when the device is opened medication is taken). Information from the device is used as proxy and sent to a remote web-based server. A reminder text message is sent to both the patient and the research assistant(s) whenever the device has not been opened within the prescribed time window (see Figure 10) (Karumbi & Garner, 2015).

However, owing to the limitations of the technology, the reading of messages by participants could not be confirmed and documented as a measure indicating adherence. Figure 11 represents the dashboard example of intakes that the server reports per patient.

Figure 11:

The EvriMED Wisepill Box Process



Source: The image was obtained from *Wisepill technologies homepage*, by Wisepill technologies, 2023, (https://www.wisepill.com/).

The graph indicating patient medication intake is illustrated in Figure 12.

Figure 12:

Adherence Calendar Illustrating Patient Medication Intake Graph for a Month

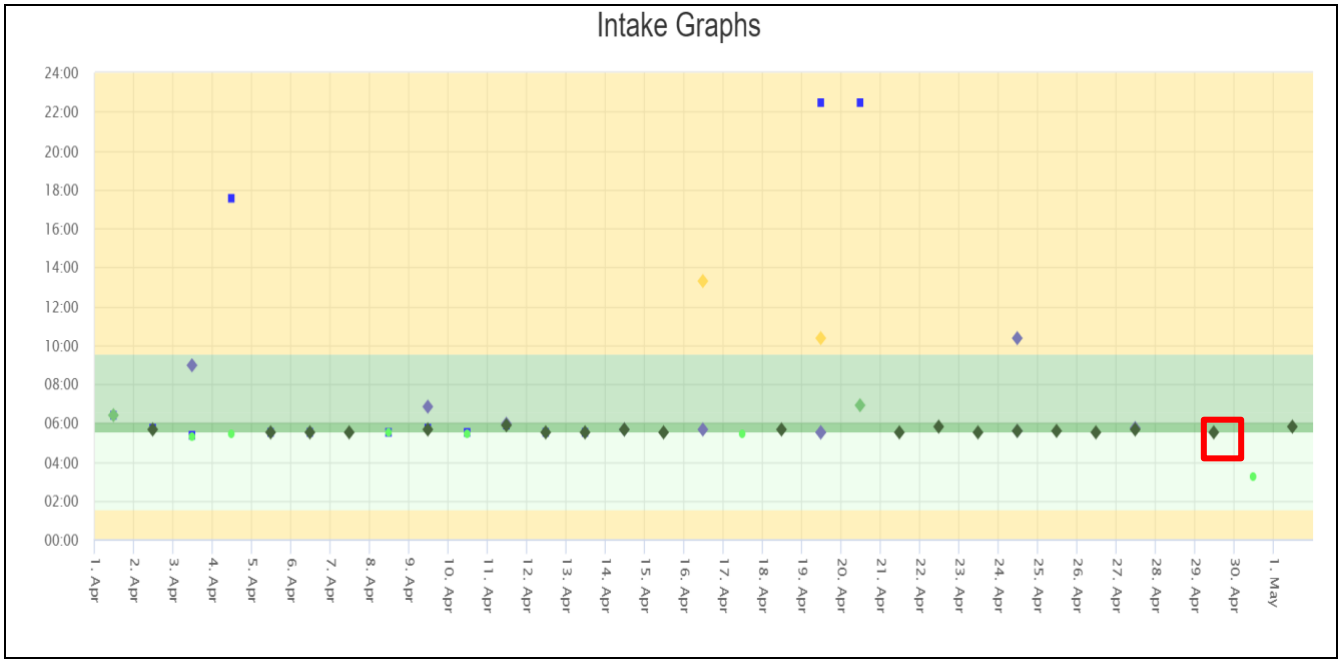


Illustration: A study patient's adherence calendar for the period between 1 April 2022 to 1 May 2022.

Medication dosing was self-administered. **Purple diamonds** indicate extra wisepill device openings. **Green diamonds** indicate wisepill device openings [i.e. 1. scheduled intake time (diamond on a dark green horizontal line), 2. Earlier (light green circles below the dark green line) or 3. Late (diamond above the dark green line)]. The **red square** indicates a missed expected wisepill device opening. The **yellow diamonds** indicate openings of the box after an SMS reminder.

Data on the patient's adherence were recorded on an mHealth platform to which only the research assistant(s) and researcher had access. Information on noncompliance (not taking medication six times in any given month) with the treatment was communicated to the facility-registered nurse. The researcher was aware that reported noncompliance with treatment, may skew the study data, and possibly result in bias. This has been taken into consideration as a limitation of the study. The research team manually recorded attempts to contact patients and instances of voice call communications as a result of patient follow-up are recorded in a call log. Behavioural, personal, and environmental factors play a role in human behaviour. Thus, the wisepill device communicated TB patients' behaviour pertaining to medication adherence and indirectly reflected their motivation to complete treatment given their perception of stigma and self-efficacy. By virtue of monitoring patients, they may be influenced by the device to adhere to timely medication use, and their motivation to adhere may translate into behavioural change (medication adherence).

4.6.1.3 Medication Adherence Self-efficacy Scale Revised (MASES-R)

The medication adherence self-efficacy scale (Ogedegbe et al., 2003) revised measure was used to measure patients' belief in their confidence to adhere to prescribed TB medications in a variety of challenging situations. This scale was administered by the researcher at baseline only. The instrument consists of 13 items measured on a four-point Likert scale ranging from "not at all sure" to "extremely sure". Of the items, 12 ask about confidence in specific situations (busy at home, no symptoms, travelling), and one item asks about confidence in ability to make medication adherence a part of the daily routine. There are no subscales on the measure, and instead the total scale score is computed by averaging across responses to all items. Higher scores indicate a greater level of self-efficacy. An explanation of the administration and completion of the scale is found in Appendix 5. The scale has not been used in South Africa before, although the instrument demonstrated good reliability with Cronbach's alpha coefficients of 0.92 and 0.90 at baseline and at three months, respectively, using a hypertensive African American sample (Fernandez et al., 2008).

4.6.1.4 Stigma Scale for Chronic Illnesses 8-item Version

The stigma scale for chronic illnesses 8-item version (Molina et al., 2013) measures internalised (three items) and enacted (five items) stigma experienced by people with neurological conditions (see Appendix 6). An example of an item for internalised stigma is: "I felt embarrassed about my illness". An example of an item for enacted stigma is: "Some people acted as though it was my fault that I have

this illness". The researcher used the SSCI-8 scale for TB because TB is classified as a chronic disease. The items are scored on a five-point Likert scale from 1 (never) to 5 (always). Total scores range from 8 to 40, with higher scores indicating higher levels of perceived stigma. The raw scores could be converted into IRT-based T-score distributions, standardised scores with a mean of 50 and a standard deviation of 10. The SSCI-8 has shown high internal consistency (Cronbach's alpha of 0.89) (Molina et al., 2013). The scale has not previously been used in South Africa (Molina et al., 2013).

The researcher was aware that the medication adherence self-efficacy scale revised and the stigma scale for chronic illnesses 8-item version used in this study have not been used in South Africa before, but in other contexts only. However, their psychometric information on the standardised assessments (Cronbach's alpha) illustrated a good reliability, with coefficients above 0.80 (Fernandez et al., 2008; Molina et al., 2013). The researcher's choice of measuring instruments was guided by extant literature on the issues affecting adherence in the context of TB.

4.6.1.5 Three-item Adherence Scale

The three-item adherence scale was developed through rigorous cognitive interviewing and was validated in the US (Fowler et al., 2016; Wilson et al., 2014; Wilson et al., 2016). It was used to measure medication-taking behaviour and adherence (see Appendix 7). The three items include: (1) assessment of number of days medication was missed; (2) frequency of medication intake; and (3) rating of adherence to medication intake in the previous 30 days. The three adherence items are linearly transformed to a 0–100 scale, with zero being the worst, and 100 the best adherence (Gaito, 1980; Townsend et al., 1984). The scale has an internal consistency value of 0.86 for a Western sample (Wilson et al., 2016). It has also been used in South Africa to investigate the association between self-reported adherence (measured using a three-item scale) and elevated viral load (VL) among 542 HIV-infected pregnant and postpartum women on ART in Cape Town (Phillips et al., 2017). The findings revealed that 12% of patients reported perfect adherence on the self-report scale, while 92% had a VL of fewer than 1000 copies/mL. Therefore, having a raised VL was consistently associated with lower median adherence scores of the scale (Phillips et al., 2017).

The researcher administered the scale to patients at follow-up visits. The participants were not required to complete the questionnaires themselves, but instead the researcher or assistant completed the questionnaires on the patients' behalf, based on their verbal responses. An average score was calculated for the three individual items.

4.6.1.6 Pill Count

Pill count was used as an outcome variable (primary outcome) for adherence to TB medication. This measure is reliable for monitoring adherence because of its objective approach (Sangeda et al., 2014). The researcher or research assistant(s) contacted the facility-registered nurse(s), who conduct pill counts during follow-up visits with patients. In most instances, the facility nurses granted the research team access to patient files to obtain this information. This contact enabled the research assistant(s) to link patients involved in the study.

4.6.1.7 Overall TB Outcomes

Overall TB outcomes were interpreted in the context of treatment success (when a patient has successfully completed a TB treatment regimen and their outcome results are indicated as cured or completed) or unsuccessful (where the patient's treatment outcome result is indicated as loss to follow-up or treatment failure). For TB treatment outcomes, the facility-registered nurse and/or medical doctor made judgements regarding the patients' TB treatment outcomes and the interpretation of these outcomes was adopted from the National Tuberculosis Management Guidelines (2014), as shown in Table 3. For this research study, information on overall TB outcomes was obtained from the patient files, to which the facility nurse granted the research team access. In addition, a summary of the key measurement instruments used in the research are presented in Table 4.

Table 3:
Interpretation of Overall Treatment Outcomes

Outcome	Definition
Cure	Patient whose baseline smear (or culture) was positive at the beginning of the treatment and is smear/ culture negative in the last month of treatment and on at least one previous occasion at least 30 days prior.
Treatment completed*	Patient whose baseline smear (or culture) was positive at the beginning and has completed treatment but does not have a negative smear/culture in the last month of treatment and on at least one previous occasion more than 30 days prior. The smear examination may not have been done, or the results may not be available at the end of treatment.
Treatment failure	Patient whose baseline smear (or culture) was positive and remains or becomes positive again at five months or later during treatment. This definition excludes those patients who are diagnosed with RR-TB or MDR-TB during treatment.
Died	Patient who dies for any reason during the course of TB treatment.
Treatment default (loss to follow-up)	Patient whose treatment was interrupted for two consecutive months or more during the treatment period.
Transfer out	Patient who was referred to a facility in another district to continue treatment and for whom the treatment outcome is not known.

*Treatment success indicated by a combination of the patients who were cured and those who completed treatment.

Source: South African National Department of Health (2014).

Table 4:
Key Measurement Instruments Used in the Study

Measuring instruments	Constructs measured
Questionnaire	Biographical information of DS-TB patients.
A three-item adherence scale	Medication-taking behaviour and adherence.
The evriMED wisepill box	Monitoring of real-time medication adherence – detailed history about the number of doses taken and other deviations from the dosing regimen.
Medication adherence self-efficacy scale revised (MASES-R)	Patients' belief in their confidence to adhere to prescribed TB medications.
stigma scale for chronic illnesses 8-item version (SSCI-8)	Measurement of internalised and enacted stigma experienced.
Pill count	Outcome variable (primary outcome) of adherence to TB medication.
Overall TB outcomes	Clinical outcomes post-TB treatment.

4.6.2 Qualitative Research Method

An interview guide was used to conduct the in-depth interviews, which are indicated in Table 5 (see also Appendix 8). The process of developing the interview guide was informed by the literature review on the topic, followed by drawing-up a list of questions to be explored. The qualitative questions were further refined through the following principles: 1) asking open ended questions instead of closed-questions (yes or no), 2) avoiding leading questions, 3) avoiding double-barrelled questions, and 4) adding probing questions. Later on, the questions developed were grouped into four sections that can answer the qualitative research question. The researcher was interested in how feedback reminders and overall use contributed to understanding how the technology was helpful to patients in taking their medication, barriers to adoption and sustainability of using the mHealth tool, the wisepill box.

Table 5:
Interview Guide Used in the Study to Interview Participants

Sections of the interview guide	Questions
End-user experiences	• What does the box **represent** to you? [Probe: Provide a metaphor to describe the box]. • What is your **opinion of using** the Wisepill box monitoring device? [Probe: Is it easy or difficult to use the device?] • How **useful** was the Wisepill box monitoring device to you? • How do you **feel about someone monitoring** how you are taking your pills every day? [whose involvement is triggered by sustained missed doses]. • What was the **reaction of people** in your environment when they saw you using the device? • Tell me about your **storage strategies** of the device when you were at home, work and when travelling. • Would you say that the Wisepill box monitoring device is **appropriate for use** among TB patients like yourself?
Influence of using the mHealth tool	• What is your opinion about the **importance of completing TB medication**?

Sections of the interview guide	Questions
	• Are you **aware of the consequences** of not completing your TB medication? Pprobe: Where did you obtain this information from? Do you know of any person who did not complete their TB medication? If yes, what happened to them? Do you think that incident motivated you to complete your TB medication?] • In using the Wisepill box, **were the reminder messages** you received, which were triggered by the device when you missed a dose, **useful?** [Probe: Did they help you to take your medication as prescribed?] • If the **reminders were not present, would you have still taken TB medication** on that day? [Probe: If no, what were some of the reasons that contributed to the non-adherent behaviour? If yes, what were some of the strategies you used to ensure you take TB medication?] • Did the **use of the Wisepill box** monitoring device **motivate you** to attend your scheduled follow up clinic visit as prescribed?
Stigma and self-efficacy	• Did you **feel embarrassed** that you had TB? If so, why? [Probe: Physical limitations that come with having TB] • Did you feel that after having been diagnosed with TB, **people around you treated you differently**? [Probe: People avoided you, were uncomfortable around you, said bad things about you – that it was your fault you contracted the disease?] • **Did you believe that what people said** about you in relation to the disease was true? If so, why? • When you started with TB medication, **were you confident that you would complete** your medication as prescribed by the healthcare professional? If yes [Probe: Highlight on motivations, goal attainment] • Do you feel that **having built this self-confidence before helped you** complete TB medication? • In your opinion, what do you think made you **stay adherent** to TB medication over time? [Probe: What situations made it easy for you to take your TB medication?] • In your opinion, what do you think made you **not stay adherent** to TB medication over time? [Probe: Difficulties you have in taking TB medications? What situations make it difficult for you to take your TB medication?]
Sustainability	• What is the **value of using wisepill** support technology in your everyday life? [Probe: Were you able to fit in the device with your already present self-management health habits?] • How was your **engagement or involvement in your own health care before and after** the use of the wisepill support device? • Did you **feel empowered when using the wisepill** box device? • How do you want your **box to look like**, if you could personalise it? [Probe: Elements such as size, alarms, structure of the box, colour, etc.] • What are **some of the barriers you experienced** with using the device, which made not adopt the device? [Probe: Design, privacy and security issues, connectivity, personalisation?] • Despite the barriers mentioned, **would you recommend the use of the wisepill** box monitoring device to other people who are on TB treatment? Why / why not?

Qualitative questions were developed by the author in June 2021.

4.7 DATA COLLECTION

Data collection was initiated once a newly diagnosed TB patient, who met the inclusion criteria, indicated their interest in the study. The facility-registered nurse assisted the research team in recruiting patients who were at the clinic until a total sample of 90 was reached. The data collection started with a pilot study on 15 February 2022. For the description of the pilot study, refer to Box 1, presented on the next page. The main data collection (including the qualitative interviews) for the study was completed on 30 April 2023.

All data collection was conducted in the clinic consultation rooms. Following the referral from the registered nurse, the research team provided the participants with the study information and informed consent document. They were informed that they could withdraw from the study without any negative consequences to their TB treatment. The team also performed quality checks to ensure that the referred patients met the inclusion criteria. Participants who agreed to participate completed a written informed consent document before data collection commenced. Follow-ups were linked to participants' routine visits during private consultations to ensure that no patient was approached or identified as a study participant in a public space in the facility. All the study participants received the pill box. Thus, the pill box was dependent on the patients' participation in the study. The participants knew beforehand that they would receive the pill box.

Tracking log sheets were used to track the patient return date(s) to link them to their scheduled routine follow-up visits for the treatment duration (see Appendix 4). The quantitative data collection took approximately 30 minutes per participant. The study identity (barcode) was linked to the patient's clinic card number. This enabled the research team to link the data of each participant, for example, for the purpose of conducting follow-up visits and interviews after the six months' treatment. All participants received an inconvenience allowance of R100 (in the form of a gift voucher that enabled them to buy from selected shops like Shoprite, Checkers, Usave or OK) at the end of the study. The compensation in the form of a R100 gift voucher was adequate because it was unlikely that patients would be requested to come to the clinics outside their routinely scheduled visit dates. Therefore, the time spent with the research staff was minimal.

Box 1

Pilot study

A pilot study was conducted with three patients (i.e. one female and two males – unemployed and single), who met the selection criteria at Goba CHC. The three participants were purposefully and conveniently sampled. They also represented, to some extent, the broader participant population which comprised young/early and middle adults, with more males than females. The majority of the broader participants were also single and unemployed. The purpose was to test the data collection tools (ease of administering the questionnaire and psychological scales) and the applicability of using the wisepill box device to support medication adherence. The patients were willing to participate in the study and curious about the wisepill device – how it worked and whether it would assist them in taking their pills. After the researcher explained and illustrated how the wisepill box functioned, the participants generally found the device interesting and welcomed the opportunity to use it throughout the six months' duration of treatment, and later shared their experience of using this device. The researcher administered the questionnaire and psychological scales. It took approximately 30 minutes to complete and to set up the device. The researcher and research assistants saw that the patients easily understood how to respond to the questionnaire and psychological scales, and to use the wisepill technology. Subsequent data collection was therefore easier as it was streamlined based on the guidance provided by the pilot study. The pilot data were included in the main study. Data were captured in the Research Electronic Data Capture (REDCap) management system and follow-ups continued until patients exited the study.

4.7.1 Quantitative Data Collection

The researcher collected the quantitative data between 15 February 2022 and 10 March 2023. Newly diagnosed TB patients were recruited and followed up until the end of their six months of treatment. The period of data collection for each patient coincided with the duration of the standard TB treatment regimen, which is six months. Patients were recruited at the start of their treatment (at initiation). A 14-day window period was used by the researcher to enrol the patients in the study. Enrolling patients within the 14-day window period enabled the researcher to increase her sample, as it was not always possible to enrol many on the same day since some patients were too ill and not in a position to give their consent.

A **sociodemographic questionnaire** was administered to obtain descriptive information (household characteristics, education level and employment status). Details about the diagnosis date, treatment start date, follow-up adherence, self-reporting, and overall TB outcomes were captured in the questionnaire. A **wisepill box** was issued to monitor patients who were part of the study from the start of their treatment until its completion. All participants received training by the researcher or the research assistants in using the wisepill box. The **stigma and self-efficacy scales** were administered individually at patient enrolment either by the research assistant(s) or by the researcher. The two research assistants were employed full-time by the project to collect the study's data.

During all six follow-up visits, patients were asked by the research team to report on their adherence to TB medication. The **three-item adherence scale** was administered at each follow-up

visit (monthly) so that patients could rate their medication intake. The research team also documented **pill counts** for every patient enrolled in the study who returned for their clinic follow-up visit.

After the six months' treatment, the researcher obtained the **overall TB treatment outcomes** from the patients' files, which were completed by the facility-registered nurse. The facility-registered nurse who assisted with recruitment provided the research team with access to the relevant patient files (only those who were enrolled in the study and signed the informed consent form).

4.7.2 Qualitative Data Collection

At the end of six months, semi-structured interviews were conducted with a conveniently selected sample in the clinic consultation room. All the participants who took part in the semi-structured interviews signed an interview consent form (see Appendix 9). The researcher attempted to establish an environment of openness and trust which, according to Hatzipapas et al. (2017), enables the participants to express their views openly. Although interviews were formally conducted in English, the participants were allowed to answer in their preferred local language, as the researcher was equipped to understand them. The researcher was therefore able to paraphrase, clarify, reflect on, and summarise the participants' answers in the local language. The interviews took between 30 and 60 minutes (i.e., mean duration of 45 minutes), and they were audio-recorded using a digital recorder.

4.8 DATA ANALYSIS

Quantitative data were analysed by means of both descriptive and inferential statistical procedures. Qualitative data were analysed using thematic analysis to establish themes. The researcher first outlined quantitative procedures and then presented the qualitative component. The integration of both quantitative and qualitative data are discussed briefly.

4.8.1 Quantitative Data Preparation and Analysis

It was important for the researcher to convert raw data into a manageable format before they were entered into the statistical analysis programme. Therefore, the following steps were followed to enable the researcher to make sense of the gathered data, eventually to answer the research questions.

4.8.2 Data Capturing, Cleaning, and Analysis

Study information was captured in the REDCap database. The data were exported and analysed in Stata 16. None of the questions in the three scales used in the study were negatively worded; hence, there was no need to recode the data. Data cleaning was conducted through running frequencies and descriptive statistics for all the data variables. The researcher had missing data in some cases, and

applied pairwise deletion. This means, the researcher did not include a particular variable in a case that had a missing value, but the case was still used for analysis relating to other variables with non-missing values. This undertaking was possible because overall TB treatment outcomes were obtained from patient files with the permission of the facility-registered nurse. The outcomes of 10 patients were transferred out. Owing to the nature of the outcome variable being binary (treatment successful or unsuccessful), the transfer-out status is defined as unknown. Therefore, the researcher instead obtained 8 of the 10 outcomes from the ETR.web.net system, as they were all treatment completed. This information was important to obtain as the sample size was small and it was going to affect the regression models.

The study data were generally not normally distributed. Therefore, the study used non-parametric statistical techniques, which are detailed under the inferential statistics section (see sections 5.1.2 to 5.1.5).

4.8.3 Descriptive Statistics

The following descriptive statistics were reported for the study: measures of central tendency, including the mean. Measures of variability were reported, including standard deviation, variance, and the minimum and maximum values.

4.8.4 Inferential Statistics

The following data analysis methods, which align with the research hypothesis, were used:

For Hypothesis 1: *Supportive feedback (reminders) from wisepill technology will increase adherence over time.* The Cochran-Armitage test was used to measure the significant increase in medication adherence over time through wisepill technology supportive feedback reminders. The main objective of trend analysis is to identify the existence or non-existence of significant increasing or decreasing trends in a data series (Mirabbasi et al., 2020). The important test assumption that the study did not violate was the adherence response pattern from wisepill technology, which was known. The adherence responses were computed as adherence rank-sum scores to interpret, from the information in the linear graph, the significant increase in adherence over time from visit 1 to visit 6.

For Hypothesis 2: *Wisepill technology scores and other subjective scores (completed medication in each month, missed dose in each month and a three-item adherence scale) will differ*. Non-parametric tests such as the Kruskal-Wallis and Mann-Whitney Wilcoxon tests were used to test the significant differences between the subjective adherence scores versus the rate of intake (adherence), as informed by the wisepill technology. Rate of intake was measured by dividing the total

monthly intake at each visit over the sum of total intake at each visit, and total missed at each visit multiplied by one hundred. The Kruskal-Wallis test was used to measure the difference among scales scores with three or more groups, and the Mann-Whitney Wilcoxon test was used when the scores were compared with two groups. The assumptions of the Kruskal-Wallis test were similar to those for the Wilcoxon-Mann-Whitney test, in that the adherence scores and scale scores were mutually independent. In addition, the measurement scales were at least ordinal, and the wisepill scores were on a continuous level of measure. Mean rank-sum scores and rank-sums for rate of intake were used to compare patient self-reporting at each visit versus the rate of wisepill intake.

For Hypothesis 3: *Adherence scores from wisepill technology will predict overall TB treatment outcomes*. The bivariate logistic regression model was used to analyse the predictive ability of scores derived from wisepill technology on overall TB treatment outcomes. The study reported on the odds ratios and the correlation (Chi-squared test) between wisepill technology and TB treatment outcomes. The Chi-square test was used to test for associations between categorical variables. Cramér's V was also used to measure the effect size of the relationship for the Chi-squared test. Kotrlik and Williams' (2003) interpretation of the Chi-squared test or Cramér's V was used (see Table 6). It is important to take note that correlation testing was not a prerequisite for running the regression model. The idea was to explore whether the relationship between the variables exists, and, if so, the magnitude of this relationship.

Table 6:
Interpretation of Φ in Chi-statistics or Cramér's V

Estimated values	Interpretation of association
0.00–0.10	Negligible
0.10–0.20	Weak
0.20–0.40	Moderate
0.40–0.60	Relatively strong
0.60–0.80	Strong
0.80–1.00	Very strong

Source: Kotrlik & Williams (2003).

The assumptions for bivariate logistic regression were all met in that the response variables were binary, they were independent of each other, there was no multicollinearity among the explanatory variables, there were no extreme outliers, and there was a linear relationship between the independent variable (*scores from wisepill technology*) and the dependent variable (*overall TB treatment outcomes*). Last, the sample size was sufficient to run the model.

For Hypothesis 4: *Stigma and self-efficacy will predict overall TB treatment outcomes even if reminders from wisepill technology are added*. The bivariate logistic regression model was used to analyse the predictive ability of stigma and self-efficacy on overall TB treatment outcomes. The study reported on the odds ratios. Spearman's rho was used to determine the relationship between stigma and self-efficacy on overall TB treatment outcome. Cohen's (1988) guideline was used to determine the strength of the relationship (see Table 7). Correlation testing in this case was not a prerequisite for running the regression model either, but instead for exploring whether the relationship between the variables existed, including the magnitude of this relationship.

Table 7:
Estimated Pearson's r Values and Corresponding Interpretations

Estimated values	Size of effect	Interpretations
0.10	Small	The effect explains 1% of the total variation
0.30	Medium	The effect explains 9% of the total variation
0.50	Large	The effect explains 25% of the total variation

Source: Cohen (1988).

The assumptions for bivariate logistic regression were all met in that the response variables were binary, they were independent of each other, there was no severe multicollinearity among the explanatory variables, there were no extreme outliers, and there was a linear relationship between the independent variable (*stigma and self-efficacy scores*) and the dependent variable (*overall TB treatment outcomes*). Last, the sample size was sufficient to run the model.

4.8.5 Qualitative Data Analysis

The 10 individual in-depth interviews were audio-recorded and transcribed verbatim by the researcher to familiarise herself with the data and to note emerging themes. Thematic analysis was used to establish the themes in the data to support the research question (Willig, 2013; 2014). The following six steps were followed, in accordance with Clarke and Braun's (2013) guideline.

Phase 1: Becoming familiar with the data

The researcher transcribed the audio-recorded interviews. She immersed herself in the data to familiarise herself with the depth and breadth of the content by repeatedly reading the generated transcripts and checking them against the original audio recordings for accuracy.

Phase 2: Generating initial codes

In this phase, the researcher produced an initial list of codes derived from the data, which was made possible through applying codes to short segments of data. The information was then organised into meaningful groups (see Table 8). During coding, the researcher also made notes on the texts that were analysed.

Table 8:
Coding List Generated from Participant Transcripts

Data	Code
Section A: End-user experiences	
Reminder to take pills	Box representation
Participant did not experience any difficulties	Using the wisepill box
To help the patient to not forget to take his pills	Usefulness of the wisepill box
Then I freaked out because I know that there is someone that is monitoring me	Feeling of being monitored
They were surprised, but then they were happy that something could help me; they were so supportive, like, even with my brother-in-law, he was, like, let me get this box. He took my pills for me, he closed you see, he said "don't forget"	Reactions to the wisepill box
I placed it where there are my cosmetics in the wardrobe	Storage strategies
Yeah, it is right, a lot. Personally, I found it useful. I saw it, it was useful.	Wisepill box appropriate for use by TB patients
Section B: Influence of using mHealth tool	
After taking the treatment, the participant felt better	Importance of completing TB treatment
Participant shared a story of his friend, whom they used to live with, who had died from untreated TB	Consequences of not completing TB treatment
Patient received reminders when he had to wake up early at 5 am to walk (accompany) someone	Reminder messages useful
The participant mentioned that she would not have taken the medication	Absent reminder messages –would you have taken pills on that day
The participant, every time he takes the medication, he ticks his clinic card and is able to see the return date for [his] follow-up visit	Motivation from the pillbox to attend clinic follow-up visits
Section C: Stigma and self-efficacy	
Patient was not embarrassed; she wanted to know the type of TB she had since she was not coughing and seemed well (at) [in] first 4 months	Feelings of embarrassment because of TB

Data	Code
Participant mentioned that they judged him and they themselves [housemates] did not know their status	People's treatment after your TB diagnosis
Patient mentioned that, yes, he knew he would complete treatment	Confident on completing TB treatment at the start of treatment
TB is curable; taking medication made the participant feel better	Reasons for staying adherent to TB medication over time
Feeling stressed on some days, I would just open the pill box and not take treatment	Reasons for not staying adherent to TB medication over time
Section D: Sustainability	
Participant travelled with her pill box everywhere and made sure to pack it first	Value of using wisepill box in everyday life
Before, the participant would forget to take treatment as prescribed	Involvement in own healthcare before and after using the pill box
Participant agreed that she felt empowered when using the pill box	Feelings of empowerment when using the pill box
Having music play from the box will get the participant interested	Suggestions to personalise the pill box
The volume of the alarm is loud	Barriers to using the pill box
The participant would still recommend this box to be given to people who are on TB treatment	Recommendation to use the device

Summary of coding list developed by author in October 2023.

Phase 3: Searching for themes

The researcher, in this phase, refocused the analysis at the broader level of themes, and sorted different codes into potential themes. All relevant coded data extracts were collated within the identified themes. The study used tables to represent visually how different codes were sorted into themes, which highlighted the relationship between codes, between themes, and between different levels of themes (main overarching themes and subthemes). Codes that did not fit into the study's main themes were called miscellaneous.

Phase 4: Reviewing themes

During this phase, the researcher reviewed and refined themes. The idea was to ensure that the coded data extracts, meaning, and collated extracts for each theme formed a coherent pattern. The validity of individual themes in relation to the data set was considered to ensure a clear distinction between

themes. At the end of this phase, the researcher had a fairly good idea of the study's different themes, how they fitted together, and the overall story they told about the data.

Phase 5: Defining and naming themes

The researcher wrote a detailed analysis for each individual theme and identified the comprehensive meaning of each theme. Each theme was fitted into the broader overall story in relation to the research question. This minimised overlapping of themes. It was nevertheless important to clarify how each theme related to the others.

Phase 6: Producing the report

In this phase, the researcher wrote a final analysis in the form of a summary report. The content derived from the data needed to convince the reader of the merit and validity of the analysis. To achieve this, the researcher used extracts and embedded them in an analytic narrative that illustrated the contextual reality of the data. This, in turn, ensured that the analytic narrative went beyond a mere description of the data, which helped to make an argument in relation to answering the research question. Although the second researcher was not available to conduct qualitative analysis, she assisted by listening to recordings and double-checking for leading questions or bias in some of the transcripts. This helped to minimise the bias.

4.8.6 Integration of Quantitative and Qualitative Results

The quantitative and qualitative results were combined to provide a more in-depth understanding of the data (Fetters et al., 2013; Fielding, 2012). Interpretation and explanation elaborated on the main findings (differences and similarities) derived from the quantitative and qualitative findings. (see Chapter 5). The researcher conducted joint display analysis based on the data collected to optimise the visual presentation of the quantitative results alongside the qualitative findings. Colour coordination (Miller & Bustamante, 2016) was used to organise and label the data to assist readers with interpreting the results that were presented (Fetters et al., 2013). The researcher's analysis in joint display was guided by Haynes-Brown and Fetters' (2021) procedures (see Table 9).

The analytic intent was to examine the extent to which the qualitative data produced by interviews supplemented the quantitative scores obtained from adherence measures. The researcher had to relate the two datasets. The quantitative and qualitative datasets were analysed separately through engagement in this iterative process of building joint displays. Both types of data were regarded as equally important to address the study's purpose. After the initial separate analyses, the

two sets of results were integrated at the interpretation stage, where qualitative data elaborated on quantitative results.

Table 9:
Critical Considerations in Joint Display Analysis

Guideline procedures to consider in joint display analysis
Compare and contrast the quantitative and qualitative data based on the findings of both data sets.
Decide on the most suitable numerical and text findings to integrate.
Consider the best approach for presenting the quantitative data (numerical or other visual).
Consider the best approach for presenting the qualitative data.
Examine the display for reader friendliness.
Look for trends and patterns across displays created.
Identify concepts, themes, patterns and anomalies in the results based on the findings of both datasets.
Incorporate theory for structuring the analysis, and for exploring emerging findings.
Look for insights across the two types of data and draw meta-inferences.

Source: Haynes-Brown & Fetters (2021).

4.9 VALIDITY AND RELIABILITY

The researcher assessed the reliability and validity of quantitative data and results, and the credibility and trustworthiness of the qualitative data and findings. According to Davis (2004), and William (2024), validity and reliability are important components in research to ensure accuracy, credibility and trustworthiness of findings. In healthcare and social sciences research, these components are paramount for the accuracy of data collected (Kimberlin & Winterstein, 2008).

4.9.1 Quantitative Research

Quantitative research is commonly dependent on using various measurement techniques to collect data on constructs that are not directly measurable. Therefore, it is important to certify the validity and reliability of the measurement used to produce meaningful results (Chiang et al., 2015). A well-conducted quality research study is determined by producing findings that are valid and reliable (Heale & Twycross, 2015). The researcher will now briefly detail the psychometric validity and reliability of the measurements used as well as the validity of the design selected for this study.

4.9.1.1 Validity

Scale validity refers to the extent to which an instrument measures the construct it was developed to evaluate (Raykov & Marcoulides, 2011). The validity of an instrument can be examined in numerous ways. The researcher outlines the most common tests for validity, namely, content validity, criterion validity and construct validity.

a. Content Validity

This type of validity evaluates whether the tests assess the full range of knowledge and content that they should with regard to the aspects of the constructs which they were designed to capture (Heale & Twycross, 2015). In addition, it is important for researchers to determine whether the questionnaire, scale or tool covers a sufficient domain related to the variable. In this study, the researcher consulted with the research nurse scientist at the South African Medical Research Council, an expert in the field of tuberculosis to review the questionnaire and the scales to ensure the relevance and accuracy of constructs being assessed. In addition, the questionnaire and scales were subjected to pilot tests.

b. Construct Validity

Construct validity refers to making inferences from operationalisations, by connecting concepts to observations in the study and applying them to the constructs on which those operationalisations are based. It is important to provide evidence that the study data support the theoretical structure (Chiang et al., 2015). The researcher used already established adherence scales (three-item adherence scale, MASES-R and SSCI-8), which accurately operationalised how constructs were measured (Shadish et al., 2002). Furthermore, to establish construct validity, measures need to demonstrate both convergent and discriminant validity (Raykov & Marcoulides, 2011). The scales were used in several research studies and, based on the psychometric properties, deemed valid and reliable (Fernandez et al., 2008; Fowler et al., 2016; Molina et al., 2013; Ogedegbe et al., 2003; Phillips et al., 2017; Wilson et al., 2014; 2016). In section 4.6, detailed information is presented on the Cronbach alpha values of each measure. For measures that have not yet been used in the South African context (MASES-R and SSCI-8), the researcher performed a pilot test to ensure that the questionnaires were understood and measured what they intended to measure.

c. Internal and External Validity

Researchers Patino and Ferreira (2018) define internal validity as the extent to which the observed results represent the truth in the population being studied and thus confirm that these results cannot be ascribed to methodological errors. It is therefore important for researchers to attempt to minimise any

threats to internal validity by controlling for all extraneous variables (García-Pérez & Alcalá-Quintana, 2012). The internal validity of a study can be threatened by many factors, such as errors in measurement or in the selection of participants for the study (Patino & Ferreira, 2018). The researcher only reflected on the threats that were relevant to the current study. The researcher did not use a control group; neither did she apply random selection when she enrolled patients in the study. Therefore, the researcher cannot conclude that the relationship between the variables of the study are causal or effectual.

External validity refers to the extent to which the results of a study are generalisable to other people (patients), especially in respect of the population that the sample is thought to represent (Patino & Ferreira, 2018). Using random assignment is a recognised method in research to improve external validity. However, this was not possible in the present study. The sample size (N=90 patients) used in the study was small. Therefore, the researcher was cautious about generalising the findings to larger populations. The study's findings may not translate into populations with different characteristics because selected patients were from a pool of clinics in Ekurhuleni; moreover, the sample was based on voluntary participation and convenience. Nevertheless, significant findings of the study could allow for some inferences regarding the relationship patterns between variables of interest and might possibly guide further investigation.

d. Statistical Conclusion Validity

The goal of research is to produce dependable knowledge or to provide the evidence that may guide practical decisions (García-Pérez & Alcalá-Quintana, 2012). Statistical conclusion validity (SCV) holds when the conclusions of a research study are founded on adequate analysis of the data. This means that suitable statistical methods are used to support the conclusions drawn by the research findings (García-Pérez & Alcalá-Quintana, 2012). Statistical conclusion validity pertains to "the extent to which data from a research study can reasonably be regarded as revealing a link (or lack thereof) between independent and dependent variables as far as statistical issues are concerned" (Cook & Campbell, 1979, pp. 39–50; Shadish et al., 2002).

To determine the credibility of the study's findings, the researcher ensured that the following three aspects of SCV were met: (1) confirmed adequate statistical power to detect an effect, if it exists; (2) lowered the risk of the study to "reveal" an effect that did not actually exist; and (3) confidently estimated the magnitude of the effect. In addition, scientifically valid and reliable measurement instruments were used to assess the variables. The data collection in this study was thus undertaken by employing quality scientific measurement instruments.

Sample size was determined by means of the Clopper-Pearson method for confidence interval, with one proportion considering the confidence level set at 95% and the expected proportion of 0.600. With a lower limit of 0 and an upper limit of 0.699, the minimum sample size required was 69. Furthermore, in determining the minimum sample size for the logistic regression model, the R-square=0.000, alpha at 0.05, with a higher odds ratio of 2.00 and the power of 0.84784 were used. The outcome therefore indicated that the minimum size required was 84. The targeted sample size was rounded off and adjusted to 90.

4.9.1.2 Reliability

Reliability is the degree of consistency exhibited when a measurement is repeated under identical conditions (Boateng et al., 2018). The research team administered three scales to the patients, two at baseline and one during follow-up visits. It is important to highlight that the conditions under which the scales were completed were similar for all patients. They all received the same instructions, and standard procedures were adhered to. Several standard statistics were developed to assess the reliability of a scale. However, the Cronbach's alpha is discussed in relation to the present investigation (Cronbach, 1951).

Cronbach's alpha assesses the internal consistency of the scale items, namely the degree to which the set of items in the scale co-vary, relative to their sum score (DeVellis & Thorpe, 2021; Cronbach, 1951; Raykov & Marcoulides, 2011). An alpha coefficient is interpreted as follows: r= 0.70, which is often regarded as an acceptable threshold for reliability; while r= 0.80 and r= 0.95 is preferred for the psychometric quality of scales. The alpha coefficient is described as robust, reliable, strong, and excellent (Cortina, 1993; van Griethuijsen et al., 2014; Revelle & Zinbarg, 2009).

Research was conducted on the psychometric properties of the scales (three-item adherence scale, MASES-R and SSCI-8) that were used in the study and found to be reliable, with a coefficient alpha of above 0.80. Therefore, the study could confidently state that the way the sample completed the scales was reliable. The reliability statistics are reported as follows:

a. Reliability Statistics for Stigma Scale

The study administered the stigma scale to all 90 patients at enrolment. The Cronbach's alpha for internalised and enacted stigma were 0.82 and 0.80, respectively, which are both above 0.80 (see Table 10), and higher than the ideal benchmark of 0.7 (de Vellis 2003). Therefore, the items in the scale were found to be sufficiently consistent and indicated that the measure was reliable.

b. Reliability Statistics for Self-efficacy Scale

The self-efficacy scale was administered to all 90 patients at enrolment. The Cronbach's alpha was 0.93 (see Table 10) and higher than the ideal benchmark of 0.7 (de Vellis 2003). Therefore, the items in the scale were sufficiently consistent and indicated that the measure was reliable.

Table 10:
Summary of Reliability Analysis of the Scale Instruments

Scales	Number of items	Average interitem correlation	Cronbach's alpha score
Internal stigma	5	0.4904	0.8279
Enacted stigma	3	0.5726	0.8008
Self-efficacy	13	0.5299	0.9361

The onus is on researcher to ensure that the measures which are used in a study are scientifically valid and reliable. This researcher demonstrated that scientifically valid and reliable measures were used for quantitative data collection. It is important that the application process of these measures, and resulting data, should be free of bias. The researcher ensured that the interpretation of quantitative data was based on sound and appropriate statistical analysis. Ensuring validity and reliability is of key relevance to generating good quality research.

4.9.2 Qualitative Research

Maintaining credibility and trustworthiness in qualitative data collection and analysis were achieved through using the following guiding principles: a) reflexivity, b) transferability, c) dependability, and d) reliability for thematic analysis (Korstjens & Moser, 2018; Noble & Smith, 2015). The study followed these four guiding principles for quality control.

4.9.2.1 Reflexivity

The researcher acknowledged her role in qualitative research, that she was part of the research study, and that her prior experiences, assumptions and beliefs would influence the research process and interpretation of findings. Therefore, during data analysis the researcher listened more than once to the audio recordings to self-judge the content of the interview. In addition, the researcher requested a fellow research psychologist colleague to listen to recordings and to double-check for leading questions or bias in some of the transcripts. The researcher provided a description of the sample, the research process involving what was done and why throughout the study.

4.9.2.2 Transferability

According to Bloomberg and Volpe (2018; 2019), transferability is defined as a fit or match between the research context and other contexts, as judged by the reader. Therefore, the study's findings are context-specific and not intended to be generalisable. However, lessons learnt in one setting might nevertheless be useful to others. Robson (2011) argues that transferability to another setting (analytical or theoretical generalisation) is possible provided the likelihood exists that findings are applicable to other situations under similar, but non-identical conditions (Patton, 1990). A measure used in the study to ensure transferability included collecting rich and detailed information through conducting interviews. This enabled the reader to gain a holistic understanding of end-user experiences of wisepill technology in supporting adherence to TB treatment.

4.9.2.3 Dependability

Bloomberg and Volpes (2018; 2019) refer to dependability as the ability to track the processes and procedures used to collect and interpret the data. It is important to note that this criterion parallels reliability, although it is not assessed through statistical procedures. The study was able to ensure dependability by providing detailed explanations of how the data were collected and analysed. In addition, the study offered transparency of the method used, which depended on the researcher's interview transcripts (Bloomberg & Volpes, 2018; 2019). In addition, the study was confirmed as credible, which the researcher ensured by providing procedures which were used as supporting evidence that the results accurately represented what was studied. Furthermore, the researcher ensured confirmability by communicating results that were reflective of the information gathered from the participants (through audio-recorded interviews that were transcribed verbatim) and not from her interpretation or bias (Guba & Lincoln, 1994).

4.9.2.4 Reliability for Thematic Analysis

The researcher checked her results several times for coding categories to confirm accuracy. Furthermore, she accurately reported (see Chapter 5) the meaning to the unit of analysis (Johnson & Christensen, 2019; Maxwell, 1992). For example, the researcher used several descriptions and/or phrases directly obtained from the transcriptions of participants' interviews (Johnson & Christensen, 2019).

4.9.3 Integration of Quantitative and Quantitative Results

Mixed methods enhance the validity of the results (Creswell, 2014; 2015; Johnson & Onwuegbuzie, 2004). Data were integrated at interpretation and reporting level. Prior to the integration, data analysis

for the quantitative and qualitative component was presented separately. This enabled the researcher to identify key findings and questions that required additional exploration. Joint displays were used to optimise the visual presentation of the quantitative results alongside the qualitative findings by using a weaving technique; therefore, presenting main findings in the narrative form (Guetterman et al., 2015; Othman et al., 2020). This integration may stimulate and expand the readers' understanding of the research matter.

In the next section, key ethical principles and the conduct of the researcher are discussed.

4.10 ETHICAL CONSIDERATIONS

Ethical approval was obtained from the University of Pretoria's Faculty of Humanities and Health Sciences Ethics Committee (HUM009/0420), National Department of Health (NDoH), and the provincial Department of Health (GP_202103_053) (see Appendices 2 and 3).

The main ethical issues this study dealt with were: a) informed consent; b) beneficence and non-maleficence; c) respect for the dignity of persons, anonymity and confidentiality; d) fair selection of participants; and e) researcher competence and expertise (Neuman, 2014; Newton, 2010; Sales & Folkman, 2000).

Participants were informed about all aspects relevant to the study prior to requesting consent from them (Willig, 2008). The participants who were willing to participate provided written consent and also gave consent to have their interviews audio-recorded (see Appendix 9). There was no risk of harm to participants (Gravetter & Forzano, 2006; 2012), although, where necessary, healthcare professionals' details (including mental health care) were provided at the clinics. All information was kept safe in locked cases during transportation and stored in a locked office. A password-protected and encrypted internet-based data management system was used. Paper-based study documents were securely stored in locked cabinets at the clinic facility in the interim period. Once all the data were collected from a patient and the electronic data verified, the structured questionnaires were delivered to the offices of the SAMRC for storage.

Confidentiality was maintained by assigning a unique barcode ID to each participant. This ensured that no personal information was connected to the data. Furthermore, text message reminders were not related to TB to protect the patients' status. Identifying information, such as names from the questionnaires and transcripts, were removed and replaced by a barcode (in the case of questionnaires), and a pseudonym (transcripts). Confidentiality was not applied in instances of reporting to the registered nurse when the patient did not open the pillbox six or more times each month. In this case, the action of not applying confidentiality was for the safety and in the best interests of the patient.

Participants were advised to store the box safely at home. Patients' recruitment and selection were based on scientific and ethical principles: no persons were discriminated against because of race, age, gender, sexual orientation, disability, education, religious belief, pregnancy, marital status, ethnic or social origin, conscience, belief, or language (Health Professions Council of South Africa [HPCSA], 2016).

The researcher was competent to carry out the proposed research and had received appropriate research ethics training (Good Clinical Practice: Beginners' course) in 2021 (see 10). The facility-registered nurses granted the research team access to patient files to document study-related information (pill counts, treatment outcomes, etc.). No changes were made to the proposal that required approval from the ethics committee.

The data, which will be stored at the University of Pretoria (UP) for 10 years, will be subjected to the following standard storage principles:

All data collected (original dataset with de-identifiable information) and other related information (transcriptions) accumulated for this research study were stored in a secure storage space (electronic data). Audio recordings were destroyed once the transcriptions and interpretation of the findings had been completed. Access to the original data remains limited only to the researcher, who took ownership of and accepted full responsibility for all data. Similar actions enable researchers to ensure the anonymity and confidentiality of participants. De-identified datasets used for analysis will be stored on the University of Pretoria's research data repository and platform for 10 years. The University of Pretoria manages, maintains, and controls this platform. All data stored on the aforementioned platforms will be disposed of and destroyed after the prescribed period and by means of the prescribed method, in accordance with the University of Pretoria's Information Management policy.

4.11 CONCLUSION

In this chapter, the aim, objectives, hypotheses, research design, and the application of mixed-methods research methods were described. The chapter concluded with a description of the integration of the quantitative and qualitative results, ethical considerations, and matters relating to validity and reliability. In the next chapter, the findings are presented.

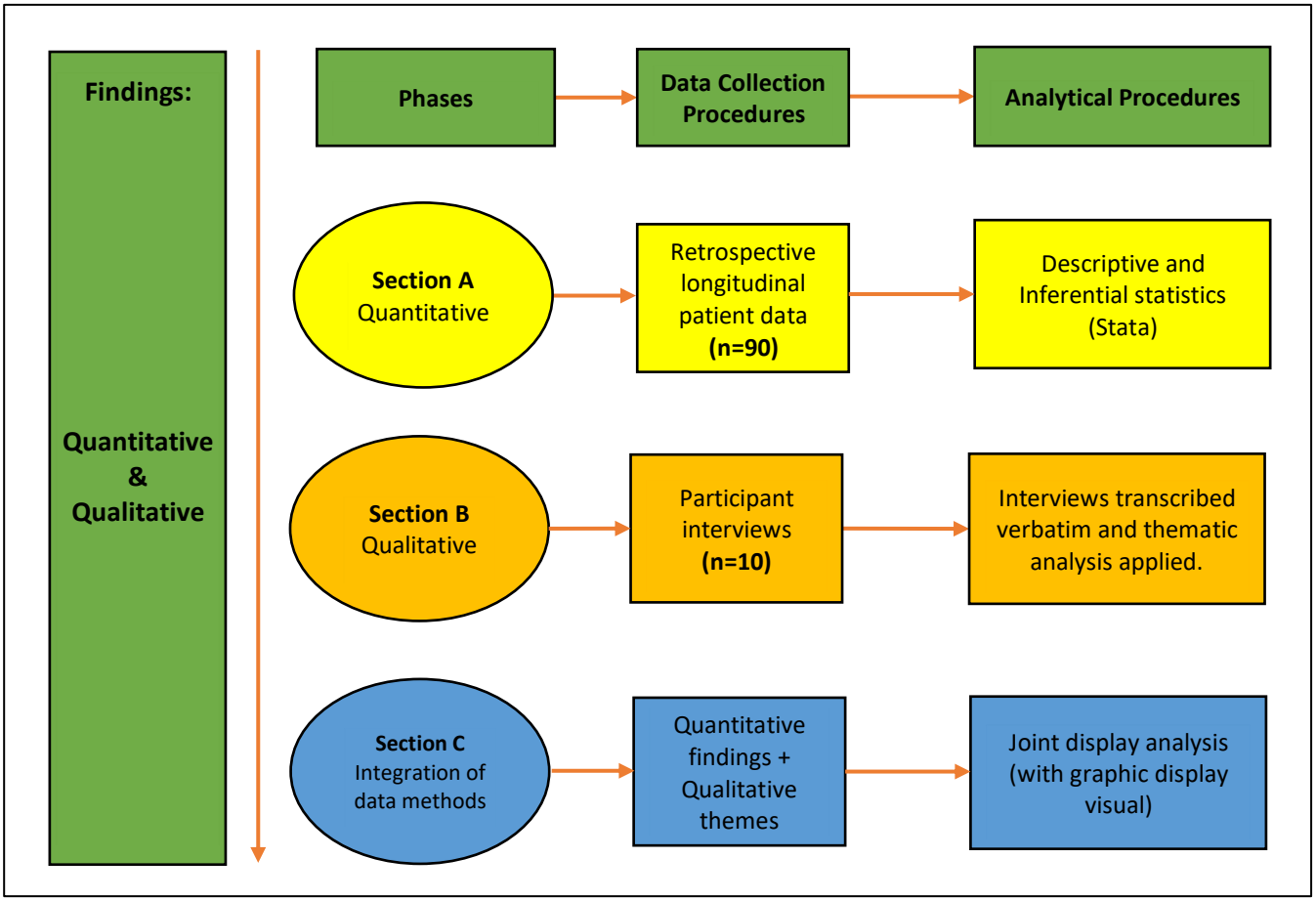
CHAPTER 5: FINDINGS OF THE STUDY

This chapter provides an outline of the results based on the quantitative and qualitative analysis applied in the study. The findings are organised in relation to the structure detailed in Figure 13.

The study's findings are divided into three sections, namely quantitative findings, qualitative findings, and the integration of both quantitative and qualitative findings, as outlined in Figure 13.

Figure 13:

Procedural Diagram Representing the Explanatory Sequential Mixed-methods Design of the Study



Source: Adapted from Ivankova et al. (2006).

The first section involves the quantitative phase of the study, which aims to determine the influence of mHealth feedback reminders on TB patients' medication adherence, given the effect of stigma and self-efficacy on adherence. This section is guided by the following:

- The description of the study sample;
- Medication adherence, including feedback reminders from the wisepill technology device, measured over six months' treatment duration;
- Scores from wisepill technology compared with other subjective scores (completed medication in each month, missed doses in each month and a three-item adherence scale);

- The predictive ability of adherence scores from wisepill technology on TB treatment outcomes was measured; and
- The predictive ability of stigma and self-efficacy on TB treatment outcomes was measured even when reminders from wisepill technology were added.

The second section provides a detailed description of the four key themes that emerged from the qualitative findings of this study. The summaries are presented in a table format to highlight the subthemes and quotes. The aim of the section is to understand, through TB patients' experiences, the barriers to adoption and sustainable use of mHealth technologies. This section was guided by the following goal:

- To explore end-user experiences of mHealth technology.

The final part of the chapter integrates and interprets data analysed from quantitative and qualitative phases, which were previously presented separately. Joint displays were used to optimise the visual presentation of the quantitative results alongside the qualitative findings (weaving technique of presenting main findings in a narrative form). The following goal guided the third section of this chapter:

- Interpreting how qualitative data enhances and elaborates quantitative results.

5.1 QUANTITATIVE FINDINGS

The quantitative findings are described in terms of the descriptive data and inferential analysis. In the section on descriptive data, the patients' sociodemographic and socioeconomic characteristics obtained from the questionnaire are documented. The researcher performed several inferential analyses to determine the influence of mHealth feedback reminders on TB patients' medication adherence, given the effect of stigma and self-efficacy on adherence. For Objective 1, trend analysis and the Cochran-Armitage test were used to measure and determine the significance of medication adherence over the six months of treatment, with feedback reminders from wisepill technology. Objective 2 used two non-parametric tests, Kruskal-Wallis and Mann-Whitney Wilcoxon, to compare the significant differences between adherence scores from wisepill technology and other subjective scores. Bivariate logistic regression analysis was used for both Objective 3 and Objective 4, respectively. For Objective 3, the regression model was used to establish the predictive ability of adherence scores from wisepill technology on TB treatment outcomes. For Objective 4, the regression model was used to measure the predictive ability of stigma and self-efficacy on TB treatment outcomes even when reminders from wisepill technology were added.

5.1.1 Demographic and Socioeconomic Characteristics

A sociodemographic questionnaire was used to obtain descriptive information regarding patients' demographic details: age, gender, household characteristics, education level and employment status. Overall TB outcomes were obtained from the patient clinic file and documented in the study file. A summary of the results is presented in Table 11.

5.1.1.1 The Sample

The total sample consisted of 90 patients (n=90). The sample was obtained from five community healthcare facilities in the Ekurhuleni district in Gauteng, South Africa. The cohort consisted of more males (n=64: 72.7%) than females (n= 24: 27.3%). The minimum age was 21 years and the highest was 82 years, with a mean age of 40 years. In relation to the marital status of patients, 68.2% (n=60 patients) were single, while 15.9% were married and 9.1% were living with a partner. In addition, 5.6% comprised patients who were divorced (n=1: 1.1%), and widowed (n=4: 4.5%). Most patients lived in a brick house (n= 63: 71.6%) or a shack (n=18: 20.5%). All patients mentioned living with at least one person inside the residential homes. The socioeconomic status data indicated a high unemployment rate of 58.6% (n = 51). Matric was the highest level of education for many patients (n=36: 40.9%), followed by partial completion of high school (Grade 10 or 11) (n=30: 34.1%). Most of the TB treatment outcomes in the sample were successful. Of the 90 patient records, 88 records had treatment outcomes that were documented. About 86.7% (n= 76) of patients had successfully completed their TB treatment regimen and their outcome results were indicated as cured or completed. Unsuccessful TB treatment outcomes accounted for 13.6% (n= 12).

Table 11:
Demographic and Socioeconomic Characteristics of the Sample

Variables	N (%)
Gender, n (%)	
Male	64 (72.7%)
Female	24 (27.3%)
Age	
Age range, min and max	21 and 82
Mean (years)	40
Marital status, n (%)	
Married	14 (15.9%)
Single	60 (68.2%)
Living with partner	8 (9.1%)
Separated	1 (1.1%)
Divorced	1 (1.1%)

Variables	N (%)
Widowed	4 (4.5%)
Residential conditions, n (%)	
Brick house on separate stand	63 (71.6%)
Shack	18 (20.5%)
Hostel	5 (5.7%)
Flat	2 (2.3%)
Employment status, n (%)	
Full-time	14 (16.1%)
Part-time	10 (11.5%)
Self-employed	6 (6.9%)
Unemployed	51 (58.6%)
Retired	6 (6.9%)
Highest level of education, n (%)	
No schooling	8 (9.1%)
Some schooling	2 (2.3%)
Completed primary school	5 (5.7%)
Completed secondary school	3 (3.4%)
Partially completed high school	30 (34.1%)
Matric/Grade 12	36 (40.9%)
Certificate/Diploma	3 (3.4%)
Bachelor's degree	1 (1.1%)
Overall treatment outcome, n (%)	
Successful	76 (86.7%)
Unsuccessful	12 (13.6%)

5.1.2 Feedback Reminders and Adherence Over Time

Objective 1:

To measure medication adherence and feedback reminders using the wisepill technology device.

The **null hypothesis** was that the supportive feedback reminders from wisepill technology device will not increase adherence over time.

Table 12:
Summary of Patient Adherence as Measurement by Wisepill Technology for Six Months Treatment Duration

Visit	Months	Observations	Median	IQR*	Rank-sum	Cochran-Armitage test (p-value)
Visit 1	1	84	27,5	22–30	15140,5	
Visit 2	2	81	30	28–31	20407,0	<0.001
Visit 3	3	75	30	28–31	19655,0	<0.001
Visit 4	4	73	30	26–31	17014,0	0.003
Visit 5	5	67	29	23–30	14915,5	0.075
Visit 6	6	63	27	12–30	11214,0	0.529

**Interquartile range (25-75 percentile).*

Table 12 and Figure 14 present findings on the significant increase in adherence over time from month 1 (visit 1) to month 6 (visit 6) after using the mHealth tool. Observations refer to the sample size of patients at each visit. The median is the number of medication intake days in each month. The rank-sum score illustrates the increase or decrease in adherence for six months, as measured by wisepill technology. The data was not normally distributed and therefore the Cochran-Armitage test was used to test the null hypothesis and to measure whether there was a significant increase over time after the first month. The Cochran-Armitage test was suitable for this analysis because it is a widely used test for trends among the binomial proportions of a dose–response relationship. This test requires preassigned fixed dose scores (Neuhäuser & Hothorn, 1999). The Cochran-Armitage test has higher power compared to the Chi-squared test when the suspected trend is correct, although the ability to detect unsuspected trends is sacrificed. The trend test exploits the suspected effect direction to increase power, but this does not affect the sampling distribution of the test statistic under the null hypothesis. Therefore, the suspected trend in effect is not an assumption that must hold for the test results to be meaningful.

Patients became fewer at each point in time point (from visit one to visit six). The number declined from 84 to 63 participants. This reduction in numbers was due to a combination of patients who transferred out, were lost to follow-up, and patients who were not opening the pill box during the study. The implications of fewer patients returning for treatment highlights the ongoing challenge faced by the TB programme, which is keeping patients adherent after initiating TB treatment.

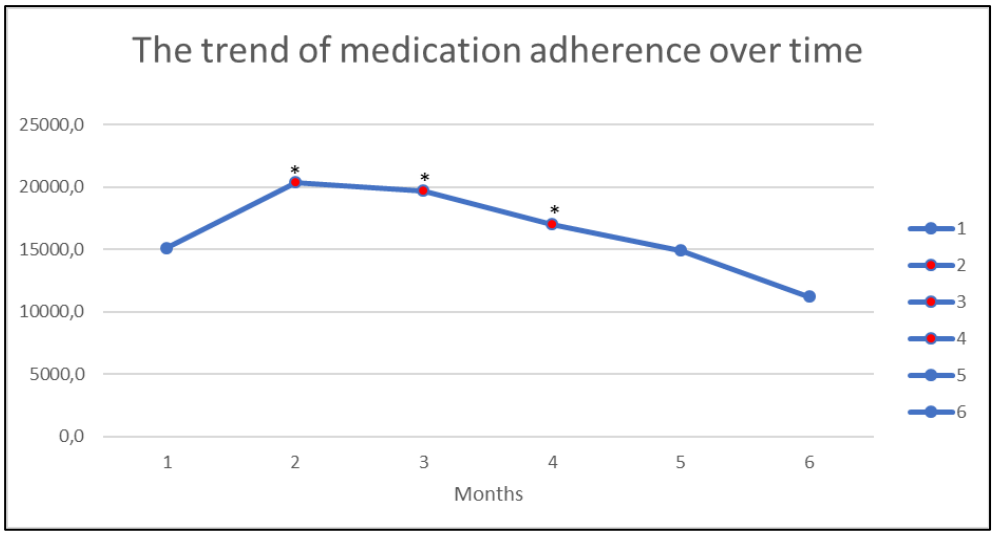
The adherence rank-sum score significantly increased from visit 1 to visit 2. This means there was a significant difference between visit 1 (n=84, *M*=27.5, IQR=22-30, rank-sum= 15140.5) and visit 2 (n=81, *M*=30, IQR=28-31, rank-sum= 20407.0), (p =.002 two-tailed).

The trend of the rank-sum scores for adherence decreased from visit 2 (n=81, *M*=30, IQR=28-31, rank-sum= 20407.0) to visit 6 (n=63, *M*=27, IQR=12-30, rank-sum= 11214.0), (*p* =.0529 two-tailed). Despite this decrease, there was a significant increase over time between visit 2 (n=81, *M*=30, IQR=28-31, rank-sum= 20407.0) and visit 4 (n=73, *M*=30, IQR=26-31, rank-sum= 17014.0), (*p* =.003 two-tailed) because all rank-sum scores between visit 2 and visit 4 were higher than the rank-sum score at visit 1.

For visit 5 (n=67, *M*=29, IQR=23-30, rank-sum= 11915.5), (*p* =.075 two-tailed) and visit 6 (n=63, *M*=27, IQR=12-30, rank-sum= 11214.0), (*p* =.0529 two-tailed), the Cochran-Armitage test indicated a insignificant increase because the rank-sum scores were less than the rank-sum score at visit 1. Additional analysis was conducted where the trend of medication adherence over time was stratified by gender (see Box 2). It was interesting to see a significant decrease in adherence for the males, as shown at visit 6. For females, a decrease in adherence was observed from visit 2 to visit 6. These findings suggest that the decrease in overall adherence over time was led by the females, specifically at visit 3 to visit 5.

Figure 14:

Illustration of Medication Adherence Trend Analysis Over Six Months



The findings relating to Objective 1 indicate that supportive feedback reminders from the wisepill technology device did not increase adherence over time. The adherence scores (given by the rank-sum) decreased between visit 1 and visit 6, although this was not significant (*p* =.0529 two-tailed). Therefore, the study failed to reject the null hypothesis.

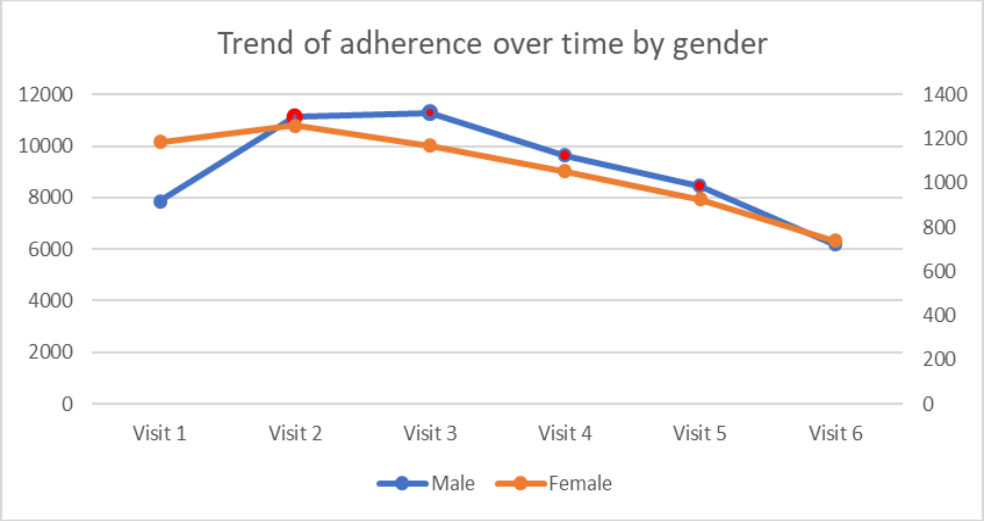
There are possible reasons why adherence did not increase over time with the use of the pillbox (which is designed to increase medication adherence). At the beginning of treatment, patients might have started enthusiastically as the healthcare staff explained the technology very well and motivated them to take their medication. In addition, the provision of a pill box to support their medication intake

was exciting to them as it was something new that came at a very critical point in their lives, when they were sick. However, over time, growing accustomed to messages could have made those feelings fade somewhat, and they felt better, forgetting to open the pill box on some days. Travelling away from home without the pill box could have contributed to the pill box not being opened. It is not surprising that we observed a decline in adherence in the continuous phase of treatment (last 4 months). Non-adherence is said to be common during the continuation phase of treatment owing to TB treatment mainly being patient-centred. Previous studies (Adane et al., 2013; Fiseha & Demissie, 2015; Mekonnen & Azagew, 2018), which analysed the treatment phase as a predictor variable for patient adherence to TB treatment, found that the continuation phase is a risk factor for non-adherence.

Box 2

The trend of medication adherence over time stratified by gender

Visits	Male		Female	
	Sum ranks	*P-value*	Sum ranks	*P-value*
Visit 1	7855		1184.5	
Visit 2	11154.5	*0.001*	1260	*0.244*
Visit 3	11259	*0.001*	1168	*0.355*
Visit 4	9633	*0.002*	1052	*0.614*
Visit 5	8452	*0.024*	925.5	*0.738*
Visit 6	6192.5	*0.798*	738	*0.394*



The trend analysis is stratified by gender. It is evident, when comparing the decline in adherence between males and females, that a steep decline was observed in females from visit 2 to visit 6. It is interesting to note as well that the decline in adherence for males was only significant at visit 6.

5.1.3 Wisepill Technology Scores Versus Other Subjective Adherence Scores

Objective 2:
To compare scores from wisepill technology with other subjective scores (completed medication in each month measured by a three-item adherence scale, missed dose in each month, and patient self-reports).

The **null hypothesis** was that wisepill technology scores and other subjective scores (completed medication in each month, missed dose in each month and a three-item adherence scale) will not differ.

Rate of intake was measured by dividing the total monthly intake at each visit over the sum of total intake at each visit and total missed at each visit multiplied by one hundred (100), as shown in the equation below.

$$Rate\ of\ intake\ score(\%) = \frac{Total\ intake\ at\ each\ visit}{[(Total\ intake + total\ missed)\ at\ each\ vist]} x\ 100$$

Non-parametric tests, specifically the Kruskal-Wallis and Mann-Whitney Wilcoxon tests, were used to test the significant differences among the subjective adherence scores versus the rate of intake (adherence) through the wisepill technology. The Kruskal-Wallis test was used to measure the difference among the scores of scales with three or more groups, and the Mann-Whitney Wilcoxon test was used when the scores were compared with two groups.

5.1.3.1 Three-item Adherence Scale

Table 13 illustrates the comparison between the rate of wisepill intake and the perception of patients at each visit of how well they took their TB medicine in the past 30 days. There was a group comparison using the Kruskal-Wallis test for the scale scores. Overall, there were significant differences among all the scores for all the visits, respectively: visits 1 (n=80, *M* rank-sum= 3240, IQR=96-100), (p =.004 two-tailed); visit 2 (n=79, *M* rank-sum= 3160, IQR=93-100), (p =.001 two-tailed); visit 3 (n=74, *M* rank-sum= 2774.5, IQR=93-100), (p =.010 two-tailed); visit 4 (n=70, *M* rank-sum= 2485, IQR=87-100), (p =.000 two-tailed); visit 5 (n=66, *M* rank-sum= 2211, IQR=96-100), (p =.024 two-tailed); and visit 6 (n=63, *M* rank-sum= 2015.5, IQR=51-100), (p =.011 two-tailed). Patients who indicated that they had been excellent at taking their TB medications had the highest mean rank scores at all the visits. It is also interesting to note that there was a decline in the excellent mean rank-sum scores over time, and this decline could be ascribed to patients' starting to report honestly how well they took their TB medicines in the past 30 days, considering that, on some occasions, they recalled missing some doses (see Figure 15).

This finding suggests that there was a significant difference between the rate of wisepill intake and the perception of patients at each visit of how well they took their TB medicines in the past 30 days. This means self-reporting on adherence behaviour was overestimated compared to wisepill intake scores. Therefore, the study rejected the null hypothesis.

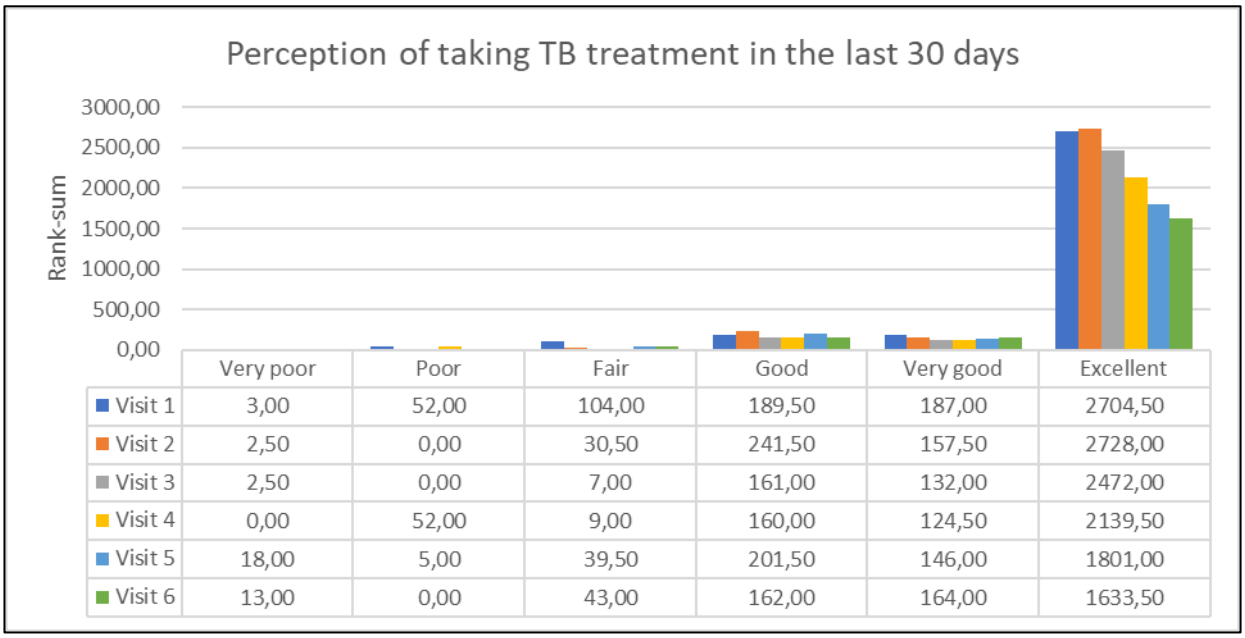
Table 13:
A Comparison Between the Rate of Wisepill Intake and the Perception of Patients of How Well they Took their TB Medicines

Time point	In the last 30 days, how good a job did you do at taking your TB medicines?							
	Very poor	Poor	Fair	Good	Very good	Excellent	Total Mean Rank-sum (IQR)	Kruskal-Wallis
	Mean Rank-sum	Mean Rank-sum	Mean Rank-sum	Mean Rank-sum	Mean Rank-sum	Mean Rank-sum		p-value
Visit 1 (n=80)	3.00	52.00	104.00	189.50	187.00	2704.50	3240 (96-100)	0.0043
Visit 2 (n=79)	2.50	0.00	30.50	241.50	157.50	2728.00	3160 (93-100)	0.0001
Visit 3 (n=74)	2.50	0.00	7.00	161.00	132.00	2472.00	2774.5 (93-100)	0.0103
Visit 4 (n=70)	0.00	52.00	9.00	160.00	124.50	2139.50	2485 (87-100)	0.0002
Visit 5 (n=66)	18.00	5.00	39.50	201.50	146.00	1801.00	2211 (96-100)	0.0248
Visit 6 (n=63)	13.00	0.00	43.00	162.00	164.00	1633.50	2015.5 (51-100)	0.0116

*Mean rank-sum score for rate of intake

Figure 15:

Patients Rated Themselves Excellent at Taking their TB Medications at All Six Visits



Patients reported that they always took medication as prescribed by the health professional. Comparing this perception to the rate of wisepill intake, two scores were significantly different for the first four visits respectively: visit 1 (n=80, *M* rank-sum= 54963.0, IQR=96-100), (*p* =.000 two-tailed);

visit 2 (n=97, *M* rank-sum= 1891.0, IQR=93-100), (*p* =.031 two-tailed); visit 3 (n=74, *M* rank-sum= 1711.0, IQR=93-100), (*p* =.038 two-tailed); and visit 4 (n=70, *M* rank-sum= 1540.0, IQR=87-100), (*p* =.041 two-tailed). However, there were insignificant differences between the patients' reporting on taking medication as prescribed by the health professional and the rate of wisepill intake for visit 5 (n=66, *M* rank-sum= 1431.0, IQR=82-100), (*p* =.267 two-tailed) and visit 6 (n=63, *M* rank-sum= 1275.0, IQR=51-100), (*p* =.117 two-tailed). Patients who indicated that they always took medication as directed had the highest mean rank scores at all the visits. The patients' mean rank-sum scores decreased over time, however (see Table 14).

Findings from the first four visits, therefore excluding visit 5 and visit 6, suggest that patients' reporting always taking medication as prescribed by the health professional differed compared to the rate of wisepill intake, meaning their adherence reporting was inaccurate. Therefore, the study rejected the null hypothesis.

Table 14:
Perceptions of How Well the Patients Took Medication in the last 30 day As Prescribed by the Health Professional Compared to the Rate of Wisepill Intake

In the last 30 days, how often did you take your TB medicines in the way that you were supposed to?								
	Never	Rarely	Sometimes	Usually	Almost Always	Always		Kruskal-Wallis
Time Point (visit)	Mean Rank- sum	Mean Rank- sum	Mean Rank- sum	Mean Rank- sum	Mean Rank- sum	Mean Rank- sum	Total Mean Rank- sum (IQR)	p-value
V1 n=80	0.00	0.00	12.00	45101.00	8 152.00	1698.00	54963.00 (96-100)	0.0006
V2 n=79	2.50	43.50	50.50	52.00	292.50	1450.00	1891.00 (93-100)	0.0315
V3 n=74	2.50	6.00	0.00	35.00	252.00	1415.50	1711.00 (93-100)	0.0383
V4 n=70	0.00	22.50	27.50	24.00	230.50	1235.50	1540.00 (87-100)	0.0411
V5 n=66	0.00	4.00	34.50	153.00	238.50	1001.00	1431.00 (82-100)	0.2677
V6 n=63	0.00	11.00	18.50	78.50	208.50	958.50	1275.00 (51-100)	0.1173

5.1.3.1 Patient Self-reporting on Completing All TB Medications

The study compared patient self-reporting on completing TB medication versus the rate of wisepill intake. The study undertook a group comparison using the Wilcoxon rank-sum (Mann-Whitney) test for the scale scores. Consequently, the study found significant differences among all the scores at all the visits respectively: visit 1 (n=83, IQR=93-100), (*p* =.000 two-tailed); visit 2 (n=79, IQR=93-100), (*p* =.000 two-tailed); visit 3 (n=75, IQR=93-100), (*p* =.001 two-tailed); visit 4 (n=71, IQR=87-100),

(*p* =.000 two-tailed); visit 5 (n=67, IQR=80-100), (*p* =.016 two-tailed); and visit 6 (n=62, IQR=51-100), (*p* =.046 two-tailed). Patients who mentioned at all the visits that they did not complete all their medication experienced a decline in the mean rank-sum scores over time (see Table 15).

Table 15:
A Comparison Between Patient Self-reporting on Completing TB Medication Versus the Rate of Wisepill Intake

Have you completed all your medications this month					
		Yes	No		Wilcoxon rank-sum (Mann-Whitney) test
Time point	**Observations**	**Rank-sum**	**Rank-sum**	**IQR**	**p-value**
Visit 1	83	189	1891	96–100	0.0002
Visit 2	79	179	1713	93–100	0.0000
Visit 3	75	201	1569	93–100	0.0012
Visit 4	71	199	1397	87–100	0.0004
Visit 5	67	346	1140	80–100	0.0166
Visit 6	62	262	964	51–100	0.0462

The findings suggest that there was a significant difference between patient self-reporting on completing TB medication compared to the rate of wisepill intake for all visits. This means patients' adherence self-reporting was inaccurate. Therefore, the study rejected the null hypothesis.

5.1.3.2 Patient Self-reporting on Missed Dose(S)

The study compared patient self-reporting on missing a dose(s) at each visit versus the rate of wisepill intake. There was a group comparison using the Wilcoxon rank-sum (Mann-Whitney) test for the scale scores. The study found significant differences among all the scores at all the visits respectively: visit 1 (n=83, IQR=96-100), (*p* =.000 two-tailed); visit 2 (n=79, IQR=93-100), (*p* =.000 two-tailed); visit 3 (n=75, IQR=93-100), (*p* =.001 two-tailed); visit 4 (n=71, IQR=87-100), (*p* =.000 two-tailed); visit 5 (n=67, IQR=80-100), (*p* =.046 two-tailed); and visit 6 (n=62, IQR=51-100), (*p* =.046 two-tailed) (See Table 16).

The findings suggest that there was a significant difference between patient self-reporting on missing a dose(s) at each visit compared to the rate of wisepill intake. This meant patients' adherence self-reporting was inaccurate. Therefore, the study rejected the null hypothesis.

Table 16:
A Comparison Between Patient Self-reporting on Missing a Dose(s) at Each Visit Versus the Rate of Wisepill Intake

Have you missed a dose(s) for this month					
		Yes	No		Wilcoxon rank-sum (Mann-Whitney) test
Time Point	**Observations**	**Rank-sum**	**Rank-sum**	**IQR**	**p-value**
Visit 1	83	1891	189	96–100	0.0002
Visit 2	79	179	1713	93–100	0.0000
Visit 3	75	1569	201	93–100	0.0012
Visit 4	71	1350	198	87–100	0.0004
Visit 5	67	1140	346	80–100	0.0462
Visit 6	62	964	262	51–100	0.0462

5.1.4 The Predictive Ability of Adherence from Wisepill Technology on Overall TB Treatment Outcomes

Objective 3: *To measure the predictive ability of adherence scores from wisepill technology on overall TB treatment outcomes.*

The **null hypothesis** was that adherence scores from wisepill technology will not predict overall TB treatment outcomes.

Bivariate logistic regression analysis was used to analyse the predictive ability of scores derived from wisepill technology on overall TB treatment outcomes. The study's findings revealed that patients who were adherent (compliant), according to wisepill technology (OR 3.93; 95% CI 1.95, 5.91; p = 0.001), were 3.93 times more likely to have successful TB outcomes compared to those who were non-adherent (noncompliant). The adherent group was classified by patients whose adherence, according to wisepill, ranged from 80% and above, whereas for the non-adherent group, this was less than 80%. Adherence to TB treatment through wisepill technology was significantly associated with overall TB treatment outcome (see Table 17). The relationship between wisepill technology and overall TB treatment outcome was determined using the Chi-squared test. There was a relatively strong, positive correlation between the two variables, chi2 = 17.42, n = 90, *p* =.000, Cramér's V = 0.4400. Higher levels of wisepill technology scores were associated with high levels of successful TB outcomes.

Table 17:
Bivariate Logistic Regression Model Indicates the Association Between Adherence Scores from Wisepill Technology and Overall TB Treatment Outcomes

Covariate	Odds Ratio	SE	p-value	95% CI
Adherence to TB treatment wisepill				
Adherence non-complaint (Ref.)	1			
Adherence complaint	3.93	1.01	<0.001	1.95-5.91

The predictive ability of scores from wisepill technology on overall TB treatment outcomes.

The relationship between wisepill technology and overall TB treatment outcome was relatively strong and significant. In addition, the study was able to demonstrate that wisepill technology predicted successful treatment outcomes. This means that adherent patients, as classified by the wisepill technology, were 3.93 times more likely to have favourable TB treatment outcomes compared to non-adherent patients. Therefore, the study rejected the null hypothesis.

5.1.5 The Predictive Ability of Stigma and Self-efficacy on Overall TB Treatment Outcome

Objective 4:
To determine whether stigma and self-efficacy will predict overall TB treatment outcomes even when reminders from wisepill technology are added.

The **null hypothesis** was that stigma and self-efficacy will not predict overall TB treatment outcomes even if reminders from wisepill technology are added.

5.1.5.1 Stigma

Bivariate logistic regression analysis was used for analysing the predictive ability of stigma on overall TB treatment outcomes. Therefore, stigma was analysed and reported as internalised and enacted, respectively. The study found that participants (n=20) who had some experience of internal stigma had 2.61 chances of having successful TB outcomes. There was a significant association between internalised stigma and overall TB treatment outcome (OR 2.61; 95% CI 1.30, 5.23; $p = 0.007$). Table 18 presents the bivariate logistic regression analysis of the relationship between internalised stigma and overall TB treatment outcome. The relationship between internalised stigma and overall TB treatment outcome was determined using Spearman's rho. There was, however, a weak, negative correlation between the two variables, r = -.146, n = 20, p =.951, with lower levels of internalised stigma associated with high levels of successful TB outcomes.

In the case of enacted stigma, the increased likelihood of patients (n=18) who experienced some enacted stigma was also significantly associated with overall TB treatment outcome (OR 2.91; 95% CI 1.28, 6.62; p = 0.011). (Refer to Table 19). Spearman's rho was used to determine the relationship between enacted stigma and overall TB treatment outcome. The study observed a weak, negative correlation between the two variables, r = -.103, n = 18, *p* =<.681, with lower levels of enacted stigma associated with high levels of successful TB outcomes.

The relationship between stigma and overall TB treatment outcomes was weak and non-significant. There were not many participants who experienced TB stigma, which could have contributed to the low relationship. However, the study was able to show that stigma (both internalised and enacted) predicted TB treatment outcomes. This meant that patients with low levels of internalised and enacted stigma were greater than 2.5 times more likely to have favourable TB treatment outcomes, compared to people who experience high internalised and enacted stigma. For that reason, the study rejected the null hypothesis. In essence, the analysis showed that stigma predicted TB outcomes and that high stigma would result in an unfavourable TB outcome and low stigma would result in a favourable TB outcome.

Table 18:
Bivariate Logistic Regression Model Indicating the Association Between Internalised Stigma and Overall TB Treatment Outcome

Covariate	Odds Ratio	Std. Err.	z	P>|z|	95% CI
Stigma (internal)					
Experienced some internal stigma	2.61	0.93	2.69	0.007	1.30-5.23

*Dependent variable overall TB treatment outcome

Table 19:
Bivariate Logistic Regression Model Indicating Association Between Enacted Stigma and Overall TB Treatment Outcome

Covariate	Odds Ratio	Std. Err.	z	P>|z|	95% CI
Stigma (enacted)					
Experienced some enacted stigma	2.91	1.22	2.54	0.011	1.28-6.62

*Dependent variable overall TB treatment outcome

5.1.5.2 Self-efficacy

Table 20 shows the bivariate logistic regression model-based association between self-efficacy and overall TB treatment outcome. The odds of patients who reported high self-efficacy (patients who rated themselves as extremely sure that they could take their TB medications all the time in various

situations) had 1.63 more chances of having a successful treatment outcome, compared those who had rated themselves as fairly sure or who did not report self-efficacy (rated themselves not at all sure).

A significant association was observed between extreme self-efficacy experience and overall TB treatment outcome (OR 1.63; 95% CI 1.39, 1.92; p = 0.001). The relationship between self-efficacy and overall TB treatment outcome was determined using Spearman's rho. There was a small (weak), negative correlation between the two variables, r = -.110, n = 88, *p* =.307, with extreme levels of self-efficacy associated with lower levels of successful TB outcomes. It is possible that patients in the beginning of treatment were overconfident in their ability to take TB treatment.

In addition, overconfidence could have resulted in their overestimated adherence to treatment. Studies (Heo et al., 2021; Vik et al., 2004; Wagner & Miller, 2004) suggest that patients' overestimation is driven by multiple factors, such as trying to avoid conflicts with the health service practitioners by presenting themselves as good patients, to be socially desirable, but they have a distorted perception of adherence to treatment.

Table 20:
Bivariate Logistic Regression Model of association Between Overall TB Treatment Outcomes and Self-efficacy

Covariate	Odds Ratio	Std. Err.	z	P>|z|	95% CI
Self-efficacy					
Fairly or not (Reference)	1				
Extremely	1,63	0.14	5.89	<0.001	1.39-1.92

*Dependent variable overall TB treatment outcome

The relationship between self-efficacy and overall TB treatment outcomes was small and non-significant. However, the study was able to demonstrate that self-efficacy predicted successful treatment outcomes. This means that patients who were extremely confident in themselves of taking their medication despite of varying situations (taking medication in a public place, when travelling, etc.) were 1.63 times more likely to have favourable TB treatment outcomes, compared to patients who had rated themselves fairly or not confident in their responses. For that reason, the study rejected the null hypothesis.

A summary of major findings from quantitative data that the study generated to answer the primary research question is presented in Table 21.

Table 21:
Summary Table Highlighting Major Findings from Quantitative Data Developed by Author in January 2023.

Objectives	Statistical test(s)	Results	Conclusion
To measure medication adherence and feedback reminders using wisepill technology.	Trend analysis and Cochran-Armitage test	*p* =.0529 two-tailed	- Supportive feedback reminders from wisepill technology did not increase adherence over time (visit 1-6). - The study fails to reject the null hypothesis.
To compare scores from wisepill technology with other subjective scores (i.e., completed medication in each month measured by a three-item adherence scale, missed dose in each month, and patient self-reports.	Kruskal-Wallis and Mann-Whitney Wilcoxon tests	*p* <.05 two-tailed (All visits, respectively) *p* <.05 two-tailed (Except for visit 5 and visit 6) *p* <.05 two-tailed (All visits respectively) *p* <.05 two-tailed (All visits respectively)	- There was significant difference between the rate of wisepill intake and the perception of patients on how well they took their TB medicines in the past 30 days. Self-reporting on adherence behaviour was overestimated compared to wisepill intake scores. Thes study rejects the null hypothesis. - There was significant difference between patients' reporting on always taking medication as prescribed by the health professional and the rate of wisepill intake (except for visit 5 and visit 6). Self-reporting on adherence behaviour was inaccurate. The study rejects the null hypothesis. - There was a significant difference between patient self-reporting on completing TB medication at each visit compared to the rate of wisepill intake. Self-reporting on adherence behaviour was inaccurate. The study rejects the null hypothesis. - There was a significant difference between patient self-reporting on missing a dose(s) at each visit compared to the rate of wisepill intake. Self-reporting on adherence behaviour was inaccurate. The study rejects the null hypothesis.
To measure the predictive ability of adherence scores from wisepill technology on overall TB treatment outcomes.	Bivariate logistic regression	(OR 3.93; 95% CI 1.95, 5.91; p = 0.001)	- Adherent patients according to wisepill technology were 3.93 times more likely to have successful TB outcomes compared to those who were non-adherent. - Adherence to TB treatment from wisepill technology was significantly associated with overall TB treatment outcome.

Objectives	Statistical test(s)	Results	Conclusion
			- Wisepill technology predicted successful treatment outcomes. - The study rejects the null hypothesis.
To determine whether stigma will predict overall TB treatment outcomes even when reminders from wisepill technology are added.	Bivariate logistic regression	(OR 2.61; 95% CI 1.30, 5.23; *p* =0.007) (OR 2.91; 95% CI 1.28, 6.62; p =0.011)	- There was a significant association between internalised stigma and overall TB treatment outcome. - There was a significant association between enacted stigma and overall TB treatment outcome. - Stigma (both internalised and enacted) predicted successful treatment outcomes. - Patients with low levels of internalised stigma and enacted stigma were greater than 2.5 times more likely to have favourable TB treatment outcomes compared to people with TB with high internalised stigma and high enacted stigma. - The study rejects the null hypothesis.
To determine whether self-efficacy will predict overall TB treatment outcomes even when reminders from wisepill technology are added.	Bivariate logistic regression	(OR 1.63; 95% CI 1.39, 1.92; p =0.001)	- The was a significant association between extreme self-efficacy experience and overall TB treatment outcome. - Self-efficacy predicted successful treatment outcomes. - Patients who were extremely confident in themselves taking medication despite of varying situations were 1.63 times more likely to have favourable TB treatment outcomes compared to patients who had rated themselves fairly or not confident in their responses. - The study rejects the null hypothesis.

5.2 QUALITATIVE FINDINGS

The qualitative findings that resulted from the interviews with a small, conveniently sampled, sample of patients (n=10) are presented in this section. The interviews were conducted at the end of treatment. The researcher identified adherent and non-adherent patients, based on the dose percentages obtained from the wisepill technology SENSE platform. Adherent patients were defined as those who took at least 80% and above of the prescribed doses, whereas those patients who took less than 80% of the prescribed doses were regarded as non-adherent. Six of the participants in the interviews were seen as

adherent, while four participants were non-adherent. These interview participants comprised six adult males, three adult females, and one elderly female. The youngest participants were 26 years old, while the eldest was 74. The majority of participants were single and had completed matric/grade 12. Refer to Table 22 for the participant demographics.

Table 22:
Participant Demographics

Participant Category	Gender	Age	Marital Status	Employment Status	Education Level
Adherent	Male	28 years	Single	Unemployed	Partially completed high school
Adherent	Male	26 years	Single	Employed full-time	Completed secondary
Adherent	Male	34 years	Single	Unemployed	Matric/Grade 12
Adherent	Female	74 years	Widow	Retired	Some schooling
Adherent	Male	30 years	Single	Employed part-time	Matric/Grade 12
Adherent	Female	28 years	Single	Unemployed	Matric/Grade 12
Non-adherent	Male	33 years	Single	Unemployed	Matric/Grade 12
Non-adherent	Female	27 years	Living with a partner	Employed full-time	Matric/Grade 12
Non-adherent	Female	29 years	Married	Missing	Matric/Grade 12
Non-adherent	Male	26 years	Single	Unemployed	Matric/Grade 12

5.2.1 Description of Qualitative Data

Thematic analysis was used to established four themes, namely: 1) end-user experiences; 2) the influence of using the mHealth tool during TB treatment; 3) stigma and self-efficacy; and 4) sustainability of using the mHealth tool.

First, an illustration of the themes is presented in Figure 16. A summary of the main overarching themes and subthemes are depicted in this figure. Thereafter, a description follows of the themes, with verbatim quotations from the interviews, as summarised in tables. The verbatim quotations are in italics.

Figure 16:

Thematic Scheme of Main Overarching Study Themes and Subthemes from the Qualitative Study Findings

5.2.1.1 Theme 1: End-user Experiences

The pillbox functioned as a reminder to participants to take their TB medication during the six months of treatment. The support from the pillbox was important for the participants' emotional and physical well-being. Beyond that, it represented their health, their motivation to take medication and their connection to life. One participant referred to it as a baby, while another saw it as a friend. The pillbox

was also represented as a clock and a storage component, referred to as a "lunch box" or "Tupperware". There were mixed reactions from participants on using the pillbox. Some found it easy to operate the device and found it useful for reminding them to take their medication in the event they forgot. They mentioned that the ease of use was brought about by not having to change the batteries themselves. Other participants, those who found the box difficult to use, expressed that their concerns were mainly driven by the fear of losing the pillbox, and their privacy whenever they wanted to use it outside their homes. One participant had negative experiences with using the pillbox as he was irritated by the loudness of the alarm. He ended up placing the pillbox in the wardrobe to minimise the sound.

The pill box supported the treatment journey of all participants. It provided them with a sense of awareness always to keep taking their medication on time, as prescribed. One participant mentioned that the pill box always reminded her to continue taking treatment, even when she felt better. The participants did not have a problem with being monitored by a professional person, who is part of the Department of Health (DOH), is knowledgeable about technology, and is not being judgemental. There were instances, however, when two participants mentioned being overwhelmed by the process. One mentioned that she did open the pillbox, and still received a reminder. Another participant mentioned that because she had not opened the pillbox, she felt ashamed to return for her scheduled follow-up clinic visit. Most participants' family members, friends, colleagues, and church members were supportive after receiving an explanation about what the pillbox does. Family members were supportive, and, in some instances, the alarm was used by the family members to wake up in the morning. One participant mentioned that her friend thought the pillbox was used for HIV medication, as TB and HIV go together. However, that did not have any negative consequences because she knew her HIV status.

The participants provided various storage strategies, such as placing the pillbox in the bedroom, dining room, the kitchen and even travelling with it to church, hospital and work. The main reason for keeping the box where they did was for easy access and to hear the alarm. The participants emphasised the importance of using the pillbox, not only among the TB patients, but also for extending its use to other people taking treatment. The participants mentioned various groups of people who could benefit from using the pillbox, such as older people, people living with HIV who are taking treatment, and people who work and find it difficult to take treatment timely. They thought that everyone could forget to take medication timely and having the pillbox could be a helpful reminder. There were no differences between the adherent and non-adherent patients in terms of their attitude towards the pillbox. A summary of the subthemes discussed is indicated in Table 23.

Table 23:
Summary of the Subthemes Highlighting the Usability of the Wisepill Box from End-user Perspectives

Theme: End-user Experiences	
Sub-theme	**Quote**
The pillbox was a companion during TB treatment	*I would say it's a reminder, every time I look at it, it reminds me of medication I have to take* ***(Non-adherent Female participant, Lilly)***. *It represents my health; that I have to be motivated to take my treatment on time (****Adherent Male participant, Billy)***. *It reminds me of my life… Yes, it gave me life* ***(Adherent Female participant, Mama Gee)***. *Yeah, to, every time when I saw it, I saw that okay I am comforted that drink, you will be alright… Yes, it was more like a friend* ***(Non-adherent Female participant, Sunshine)***. *But then she told that when you become sick with TB tell them to give you the Tupperware to put your pills in and it will remind you about taking them* ***(Adherent Male participant, Owen)***.
Usability of the pillbox	*Because, sister, you see, because somewhere somehow this thing angered me for ringing and making noise****(Adherent Male participant, Owen)***. *For me it was easy because sometimes even if I forgot to take my medication when the alarm rings and then I just remember that I have to take my medication, so it was easier for me to use it (****Non-adherent Female participant, Lilly)***. *Yeah, it was very easy to use 'cause sometimes you forget, or I am sleeping and then, when it rings, even my daughter would say, it's ringing, and then she will take it, give it to me, take out the pills, and says, drink, you see* ***(Non-adherent Female participant, Sunshine)***. *Difficult, because this box is my privacy, this box, I would take it to visit somewhere with this box, right, what if it gets lost, where I'm visiting.* ***(Adherent Male participant, Billy)***.
The pillbox was helpful in participants taking medication every day	*… it was something that I always had in the bedroom, even, even if it didn't ring, maybe, but by seeing it, I would remember that there are pills to take, and when you open, there are pills inside, for the entire six months, you see* ***(Adherent Male participant, Joe)***. *… it's, like, it was really useful, the way I used to see it, it's like, it used to update me to take my medication on time* ***(Non-adherent Male participant, Bruce).*** *Hundred percent, hundred percent because now I don't want to lie, I should have defaulted* ***(Adherent Female participant, Tee)***. *Very useful, very useful, 'cause if they had set it to ring at eight in the morning, there is no way I would miss my treatment, and it's not like an alarm, with an alarm you can just switch it off, but this one you have to open the box for it to stop ringing, yeah* ***(Non-adherent Female participant, Sunshine)***.
Feelings of being monitored remotely	*I feel like being monitored by a professional person who is a, who've got a right to tell me what to do, not somebody, not* [a] *person from outside. I think that person will be judging me…And then the wanna make sure, they not like being on top of my neck you know...that my health is still fine, so I didn't, like, mind anything* ***(Adherent Male participant, Jabu)***. *It made me freak out every time. I still remember that day I forgot… I was even ashamed to come to my date; it's my date* ***(Adherent Female participant, Tee)***. *It was a good idea actually. I wanted it 'cause I was sick for a very long time and I didn't know what was wrong with me* ***(Non-adherent Female participant, Lilly)***. *It was helpful, although one would receive a message even when I have opened the box* ***(Adherent Male participant, Joe)***.

Theme: End-user Experiences	
Sub-theme	**Quote**
A generally positive reaction to the Wisepill box	*It's just my sisters who saw it at home; they applaud it and said it is grand for storing pills* ***(Adherent Male participant, Joe)***. *…even my family came here, and saw it; they asked, "what is this now?" and then I told them, and they also recommended it, yeah, it's a good thing, so I should use it* ***(Non-adherent Female participant, Lilly)***. *Uhmm they never took me somehow, they just saw that I love my life, you see… Yeah, its like, yeah, they just took it more positive, you see* ***(Non-adherent Male participant, Bruce)***. *Yah, because they were so happy about the way I was doing things in terms of my treatment* ***(Adherent Female participant, Tee)***. *They were surprised, but then they were happy that something could help me, they were so supportive, like, even with my brother-in-law, he was like let me get this box, he took my pills for me, he closed you see, he said, don't forget* ***(Non-adherent Female participant, Sunshine)***.
Varied storage strategies	*Also, children … eh the safety, because we know… uhm that small children, we have to be careful how we put things* ***(Adherent Male participant, Owen)***. *Then you come back plus it's in the comfort of your own room placed very well, nobody knows* ***(Adherent Male participant, Jabu)***. *I keep it just here close to the TV* ***(Adherent Female participant, Mama Gee)***. *… so I would take it with me and go to the hospital, so I would take my medication there* ***(Non-adherent Female participant, Lilly)***. *Yes I moved it to my bedroom* ***(Non-adherent Male participant, Mpilo)***. *I would say that 'cause they would come into my come into my room, they see it* ***(Adherent Male participant, Joe)***. *Because I wake up every morning, feeling hungry, so immediately when I wake up, I go to the kitchen and I saw, I see the container; that's when it reminds me of taking the medication, sometimes, I take it earlier, before the alarm, the alarm, yes, yes. So yeah* ***(Non-adherent Female participant, Lilly)***.
Pillbox is suitable for anyone taking treatment	*No, all patients, all patients, all different like … uhm … sickness…* ***(Adherent Male participant, Jabu)***. *...so it's very important to have containers like this, to have people, remind people to take their medication until they finish the course…Yes, it is appropriate, remember TB spreads easily so when the container is there, is there to serve an important issue, you see. If you take your medication regularly, it's a good thing because it won't affect people around you* ***(Non-adherent Female participant, Lilly)***. *The box, I can say that, yeah, there was help but now I ask myself that, okay, this box, is it for people with TB only or everyone? You see, 'cause sometimes there are people living with HIV, you see, maybe I'm thinking that it can also be helpful to them too, but I don't know* ***(Adherent Male participant, Joe)***. *It's perfect for older people* ***(Adherent Female participant, Mama Gee)***. *Yes, it is very appropriated because most of people, they default* ***(Adherent Female participant, Tee)***. *Maybe he also works and it could be a problem* [taking their medication] ***(Adherent Female participant, Mama Gee)***.

5.2.1.2 Theme 2: Influence of Using an mHealth Tool During TB Treatment

All participants agreed to TB treatment because it was lifesaving, and it reduced transmission. The participants mentioned feeling better, healed, living again and back to their normal selves after taking their medication. One participant mentioned that she gained weight again. Living with others also drove the participants to take treatment to avoid infecting others with TB. Furthermore, not taking good care of yourself by not taking TB treatment will lead to developing other diseases or death.

Feedback reminders from the wisepill technology encouraged the participants to take their TB treatment. Participants felt that the technology was helpful whenever they forgot to take their medication. In essence, the wisepill box helped participants not to skip taking medication and to take it on time. Participants, however, had mixed reactions to missing a dose in the absence of reminder messages. Many of the participants mentioned that they would have taken their medication in the absence of reminders, although not at the committed, scheduled time. Others felt that they would have skipped taking their medication in the absence of reminders. It is interesting to note that, seeing the wisepill box (without the alarm and SMS reminders), participants were already primed to remember to take their TB medication. Therefore, they would still have taken treatment at varying times and not at the time they committed to take their pills.

The participants were motivated by the wisepill box to attend their scheduled clinic visits. One participant mentioned that he kept his clinic card inside the pillbox, and whenever he took his pills, he ticked off the date on the clinic card. The participants were also reminded by the orange flashing light from the wisepill device a day before their clinic visit. This function was pre-set for them and explained by the researcher at enrolment. The light flashed a day before their scheduled visit, so they knew automatically that they would have to go for their follow-up visit the next day. A summary of the subthemes that were discussed is detailed in Table 24.

Table 24:
Summary of the Subthemes Relating to the Influence of Using an mHealth Tool During TB Treatment

Theme: Influence of Using an mHealth Tool During TB Treatment	
Sub-theme	**Quote**
TB treatment is lifesaving	*I don't know about other people, I'll talk for myself. I'm scared of getting sick, even if I have a headache, I'm just going to get bored, because I can't work, maybe. I like to do things for myself, so TB is hurting my body. I was so sick in such a way that even if I cough I was bleeding, so it was bad. So I would advise that people should take their treatment, finish it, because when they don't, it comes back and comes back worse. We were told that in the clinic, so why must you fight a losing battle?* ***(Non-adherent Female participant, Sunshine)***. *Because I was sick and I wanted to live* ***(Non-adherent Female participant, Sunshine)***. *Yahh, like you have to take the medication to get better* ***(Adherent Male participant, Jabu)***. *Yeah, you should have taken treatment, then you complete it, then you go(ing) back to normal* ***(Non-adherent Male participant, Bruce)***.
Taking treatment reduces TB transmission	*Eh, sister, it's very important to finish your medication because we live with other people, sister. You are not living by yourself, some are involved with you, and you see that their lives are at risk, and there are children and older people mixed up in all this* ***(Adherent Male participant, Owen)*** *Isn't it when you are coughing, and you are sitting with other people and you do not take your treatment, you will end up infecting other people, and it will spread a lot in the area you are from* ***(Non-adherent Male participant, Bruce)***.
A major consequence of not taking TB treatment is death	*So now I knew that TB would kill me. If I don't want it to kill me, but you don't want to die* ***(Adherent Male participant, Owen)***. *I think, if you are not completing your treatment, it may lead to other diseases or it makes your body vulnerable, yes****(Non-adherent Female participant, Lilly)***. *Yeah, like, obviously you are going to die; yeah, you are going to die* ***(Non-adherent Male participant, Bruce)***. *You can see you can read what's the consequences, you will die because my friend that I had in Cape Town, she has a, I wasn't aware of TB at the time, now she has MDR, the one that is called XDR* ***(Adherent Female participant, Tee)***.
Feedback reminders encouraged medication intake	*Erh, it was useful because … uhm … it was like it didn't take like more than 30 minutes to remind you from your time of taking the pills so that you can still take the medication* ***(Adherent Male participant, Jabu)***. *They have helped me, my sister, even though sometimes I would miss the time, I would still take the medication* ***(Non-adherent Male participant, Bruce)***. *You see, the phone will tell you that you have left something behind* ***(Adherent Male participant, Joe)***.
Mixed reactions over taking treatment in the absence of feedback reminders	*That is something I was always aware of, that I have to take my medication; I was not going to forget that I have to take my medication* ***(Non-adherent Male participant, Bruce)***. *Yeah, I would remember but not on time...* ***(Adherent Male participant, Billy)***. *I did not see myself taking medication* ***(Adherent Female participant, Tee)***. *As I said to you, the container was in the kitchen, so every time I felt hungry, I would go to the kitchen, then, even if the reminder wasn't there, I would remember by seeing the container… Yes, so if the container wasn't there, then I wouldn't remember that I have to take my meds …* ***(Non-adherent Female participant, Lilly)***.

Theme: Influence of Using an mHealth Tool During TB Treatment	
Sub-theme	**Quote**
mHealth technology motivated participants to attend scheduled follow-up visits	*There was this light, what did she say, the sister who gave me the first time, explained that the box would ring when you have to take your medication, and then, when the date is close, it would continuously flash the light, so* ***(Adherent Male participant, Joe)***. [The participant's family, when they saw the flashing light from the box, called her out and she mentioned that it meant her clinic appointment was the next day.] *They will be like, Tee Tee, come, and then I explain, no, tomorrow is my date.* ***(Adherent Female participant, Tee)***. [The participant, every time he takes the medication, ticks his clinic card and can see the return date for his follow-up visit.] *That means I'm always seeing the date to come back to the clinic"****(Adherent Male participant, Jabu)***. *Yes, and I have never missed* [a clinic visit], *and to prove that I'm afraid of TB* ***(Adherent Female participant, Mama Gee)***.

5.2.1.3 Theme 3: Stigma and Self-efficacy

Most participants were not embarrassed because of their TB-diagnosis status. One participant, however, at the beginning of TB treatment felt ashamed, emotional, and scared. Four participants (including the one who felt embarrassed because of his TB diagnosis) mentioned that people were badmouthing them about their illness. In some instances, they were being avoided for fear of being infected. Instead of being concerned and consumed about how others would perceive them, participants removed themselves from the company of these individuals, but it did not affect them. The focus was on finishing the treatment, getting better, and living.

It was interesting to note that, although most participants were open about their TB status, some people around them thought that they were infected with HIV or even the coronavirus. Thus, they did not believe the participants. There were, however, a few instances when participants expressed their gratitude over the support and encouragement they received from their family and church members.

Participants wanted to be cured from TB. Their self-confidence was key in completing TB treatment. At the beginning of the treatment, a few participants were not confident that they would be able to complete the six-month course of treatment. Six months for taking treatment was perceived to be a very long time, so much so that one participant wanted to give up and stop taking his medication. However, during treatment these participants received support from family members and the facility nurse (who initiated them on treatment) to continue taking the treatment.

Another motivation that drove participants to complete their TB treatment and strive to live was the knowledge that TB is curable. This motivation helped them not to miss taking medication daily and to take responsibility for their lives. The participants mentioned forgetfulness and being busy (work-related), living alone, having no family support, and taking other chronic medication in addition

to TB pills (pill burden) made them not take their medication on time or visit the clinic facility as scheduled. A summary of the subthemes discussed is presented in Table 25.

Table 25:
Summary of the Subthemes of the Influence of Stigma and Self-efficacy During the TB Treatment

Theme: The influence of stigma and self-efficacy during TB treatment	
Sub-theme	**Quote**
Having TB is not an embarrassment	*No, they must know that'(s) this thing exists, and it is curable… to tell the truth, I have never felt embarrassed* ***(Non-adherent Male participant, Bruce)***. *No, sister, I was not feeling embarrassed at all because I had told those who I live with, it's just that there are a lot of people with TB and they don't know that they have TB, they live with it. At least I know because I went to the clinic, and I can be able to be on treatment. Instead of being killed by something that you did not even know you had, you see… its better to know your status* ***(Adherent Male participant, Owen)***. *Ah no I didn't, my sister* ***(Non-adherent Male participant, Mpilo)***.
Negative treatment from others due to the TB illness	*I still hear the bad mouth… Yah, they will be not comfortable around you. So that's the reason, they say, ahh, I have AIDS… things like corona* ***(Adherent Male participant, Jabu)***. *No, sister, they were saying bad things, saying this person is sick and stuff… yah, I was seeing and realising that there was a huge difference in my life… yah, saying that to my face that this person is sick and will infect all of us in the house. Now, eish, sister, I was also starting to believe the things they were saying, that I will make them sick. That is why I ended up deciding to move from their house* ***(Adherent Male participant, Owen)***. *I just told them I have TB and whoever decided to visit, visited; others stopped coming, they are no longer visiting me, and I just decided to carry on with my life* ***(Non-adherent Male participant, Bruce)***. *Oh, others thought of something else like HIV, what, what, they thought, they had in their minds, they didn't even think of TB, yeah* ***(Non-adherent Female participant, Lilly)***.
Self-confidence is key for completing TB treatment	*Uhmm … yes, I was, because my sister had TB and got cured and she used to tell me that if I stopped taking the medication this and that would happen* ***(Non-adherent Male participant, Mpilo)***. *And then I didn't hesitate to take my medication* ***(Adherent Male participant, Jabu)***. *Eish, all I wanted was to be cured"****(Non-adherent Male participant, Bruce)***. *No, sister, I had no confidence that I would finish the six months, I saw it as a long time…"****(Adherent Male participant, Owen)***. *Yeah, sister, what motivated me the most, there are so many people* [on] *medication, I'm not the only one … I would tell myself that I won't be defeated by someone who takes their medication until they die. I can't fail in six months, yeah* ***(Adherent Male participant, Billy)***. [No, the patient saw that six months was a very long time and when he felt better, he wanted to stop but was encouraged by family members to continue and complete the treatment,] *Yes, I was very sure, 'cause, I, I don't give up easily, I am a fighter; they know me, even my clients, they know that if they try and fail, I will still try, I will try my best …* ***(Non-adherent Female participant, Sunshine)***.

Theme: The influence of stigma and self-efficacy during TB treatment	
Sub-theme	**Quote**
Knowledge of TB being curable made participants stay adherent	*I know that it can be cured* ***(Adherent Male participant, Jabu)***. *I wanted to live* ***(Non-adherent Female participant, Sunshine)***. *That's what I wanted, to get healed and go back to normal, get my normal weight back, that's what I wanted, and now I can see that at least I am getting there, some big cheeks are visible* ***(Non-adherent Male participant, Bruce)***. *... I wanted to make sure that I achieve a goal, neh, to finish my medication so that I can feel better...* ***(Non-adherent Female participant, Lilly)***. *There were people near me who also told me to keep taking the medication and not stop, encouraging me to keep going* ***(Non-adherent Male participant, Mpilo)***. *This thing of it ringing reminds me that, man remember, eh, you have to take your pills, this is your life, it's not other people's. You see, we are here at the clinic, they are helping you, you get me, sister… At the end it's my life and I still want to live, so taking medication is the only way* ***(Adherent Male participant, Owen)***.
Various individual reasons for not remaining adherent to treatment	*I forget everything… Yah, you are rushing to go to work...medication can wait. It happens* ***(Adherent Male participant, Jabu)***. *I used to stay alone* ***(Non-adherent Male participant, Mpilo)***. *Eish, sister, you know, the family's support, you know, it counts somewhere somehow, sister. You see, when you got there, yah, and there is no family there or … or someone helping you to take your treatment, eh, it's not easy, sister* ***(Adherent Male participant, Owen)***. *...and then, when you count the pills that you have to take and they become a lot, it bothers me* ***(Adherent Female participant, Mama Gee)***. *Mhm, then maybe you starting, eish, to start to think negatively about the pills, that maybe they are the ones giving me a headache* ***(Adherent Male participant, Jabu)***. *I like to be busy a whole day* ***(Adherent Female participant, Tee)***

5.2.1.4 Theme 4: Sustainability of Using the mHealth Tool

The wisepill box was well integrated into the participants' lives and formed part of their health management. The pillbox was helpful, contributed to participants being organised, and to consistently taking their TB medication on time. One participant mentioned that his treatment involvement before using the wisepill box was difficult; he was unable to take medication at specific times.

The pillbox empowered participants to keep moving through providing support during their treatment journey. It also instilled a sense of hope and a reason to live. The support from the pillbox promoted patient-centred care. As a result, this support created a positive health outlook and increased the progress experienced by participants. The nurses were also pleased about the participants' progress with their treatment.

Although the pillbox was helpful, the participants mentioned a few suggestions that could be added to the device to enhance the end-user experience. They suggested that the pillbox should come in a variety of colours, it needed to have spacious compartments to fit all the monthly pills, to lower the volume of the alarm (as it was too loud for some participants) and, to have a Bluetooth-enabled feature that could connect to the phone to play music (to set the music as alarm).

A minor challenge was identified with using the wisepill box by two participants. The devices were malfunctioning owing to network and connectivity issues. This challenge affected communication with the server. Participants reported receiving reminder messages even after they opened the pillbox. For another participant, the alarm did not ring at the scheduled time.

The majority of participants recommended the use of the wisepill technology. The most important emphasis was that it helped participants to keep track of their treatment, not to skip taking their medication daily, and to take their medication on time, as prescribed. The pillbox was seen as a supportive tool that could also be used by other patients on chronic medication, for them to take their treatment regularly and on time. A summary of the subthemes discussed is detailed in Table 26.

Table 26:
Summary of the Subthemes Illustrating the Sustainability of Using the Wisepill Box Technology

Theme: Sustainability of the mHealth technology	
Sub-theme	**Quote**
It was part of my life	*It rings, I'm going to take my pills. I didn't hide those pills when I take them, I didn't hide them out…that's why I took it everywhere … everywhere I go, it was part of my life* ***(Adherent Female participant, Tee)***. *No, it didn't, it didn't disrupt anything* ***(Adherent Male participant, Jabu)***. *… because the box was here, I was adherent and took them on time. I would take them at 7* ***(Adherent Female participant, Mama Gee)***. *No, it fitted perfectly, sister. You know, I never had a problem because in the end it was helping me to overcome my problems of not taking my medication… To never forget to take my pills on time on any day, Now I love it* ***(Adherent Male participant, Owen)***. *Oh, yes, yes 'cause sometimes we are not organised, you see. So having this lunchbox made you organised and you know where to put your medication.,It makes things easier and, yeah…it made things easier.* ***(Non-adherent Female participant, Lilly)***. *Before the box it was difficult* ***(Non-adherent Male participant, Mpilo)***. *No, to be honest, I did not take the medication at the same time; there were differences in time* ***(Non-adherent Male participant, Bruce)***.

Theme: Sustainability of the mHealth technology	
Sub-theme	**Quote**
Pill box empowered participants to keep moving	*But when the box was introduced to me and then I saw hope and felt that hope… because I know that on my side there is this … erh support, yah, this support, even if it doesn't talk; it doesn't have a mouth to talk but it has its own way to communicate* ***(Adherent Female participant, Tee).*** *Every time I say this baby was a hope; each and every day there was a hope, then it pushed me and then till now* ***(Adherent Female participant, Tee)***. [Participant reported that his health progress was positive and the nurse was very happy.] *Yeah, very very happy, everyone was happy* ***(Non-adherent Male participant, Bruce)***. [The participant felt that she was in control of her health] *Yah, just in control* ***(Adherent Female participant, Tee)***. *I don't know how to explain it, but I felt empowered, I think* ***(Non-adherent Female participant, Lilly)***.
Personalising the pill box	*I think, if it was possible, just that I don't know if it's possible though, I would want to be connected to my phone, more like a phone, so that I can change the ringtone, so you just go to the app … ye, pill box, and change yeah… One thing I would change with the alarm, maybe rather people have a choice of the music, choose the song you like … maybe I will add shelves because I had to cut some pills like strips, I will put maybe fours, and usually I would like to pack my wardrobe (a)* [to] *be neat. So, I would just add shelves, yeah* ***(Non-adherent Female participant, Sunshine)***. *Sound you know, put gospel, you know… Bluetooth (wiser), and send via Bluetooth, you know, yeah, you get me, connect with Bluetooth when it rings, the alarm it would ring on this side as well, you see* ***(Adherent Male participant, Billy)***. *The size,'cause sometime they would give us medication, you see, and you find that sometimes there's more that could fit the box, sometimes when you put them inside the box, they would not all fit in there. So, the size, I could say that it was small* ***(Adherent Male participant, Joe)***.
A highlighted barrier of using the pill box was network connection issues	[When the pill box started to malfunction, connection issues were experienced. It showed all the lights and the alarm was not ringing, like it's supposed to, even after replacing the batteries.] *It's that it didn't want to ring properly* ***(Adherent Female participant, Tee)***. *Yes, and when it's about half an hour, then close it but when you close it, same time it will ring the whole night… there was a time it did not ring properly and on time* ***(Adherent Female participant, Mama Gee)***.
Recommendation to use the pill box	*Because they will never miss time* [to take medication] ***(Adherent Male participant, Jabu)***. *... that you take your treatment like, correctly and on time, yeah* ***(Non-adherent Female participant, Sunshine)***. *No, I would tell them, sister, that no, take this box man, it works and it helps … Yeah, somewhere somehow it makes things simple even on the patient to keep track of taking their treatment right* ***(Adherent Male participant, Owen)***. *Yah, so it … normally 100%; it's very helpful and I guarantee with it* ***(Adherent Female participant, Tee)*** *Yeah, because it makes sure that medication is taken on time, go accordingly, so that at least you do not miss your medication by more than an hour…* ***(Non-adherent Male participant, Bruce)***. *Yahh, sister, it's something that helped me, it will help them too, even if you sleep after you have forgotten, it will ring … ti ti ti … continue to ring until you remember to take your pills"****(Non-adherent Male participant, Mpilo)***.

A summary of major themes from qualitative information, which outlines codes, subthemes, and quotes used are presented in Table 27 to answer the secondary research question

Table 27:
Summary of Qualitative Findings Organised Into Codes, Themes, Subthemes, and Sample Quote Developed by Author in January 2023

Theme 1: End-user experiences		
Codes	**Subthemes**	**Sample quote**
Box representation	The pillbox was a companion during TB treatment	*It reminds me of my life… Yes, it gave me life* ***(Adherent Female participant, Mama Gee)***.
Using the wisepill box	Usability of the pillbox	*Because sister, you see because somewhere somehow this thing angered me for ringing and making noise* ***(Adherent Male Participant, Owen)***.
Usefulness of the wisepill box	The pillbox was helpful in participants taking medication every day	*… it's like, it was really useful, the way I used to see it, its like, it used to update me to take my medication on time* ***(Non-adherent Male participant, Bruce)***.
Feeling of being monitored	Feelings of being monitored remotely	*I feel like being monitored by a professional person who is a, who've got a right to tell me what to do, not somebody, not person from outside. I think that person will be judging me…And then the wanna make sure, they not like being on top of my neck you know...that my health is till fine, so I didn't like mind anything* ***(Adherent Male participant, Jabu)***
Theme 1: End-user experiences		
Codes	**Subthemes**	**Sample quote**
Reactions to the wisepillbox	A general positive reaction to the Wisepill box	*They were surprised, but then they were happy that something could help me, they were so supportive, like even with my brother-in-law, he was like let me get this box, he took my pills for me, he closed you see, he said don't forget* ***(Non-adherent Female participant, Sunshine)***
Storage strategies	Varied storage strategies	*I keep it just here close to the TV* ***(Adherent Female participant, Mama Gee)***.
Wisepill box appropriate for use by TB patients	Pillbox is suitable for anyone taking treatment	*Yes, it is very appropriated because most of people they default* ***(Adherent Female participant, Tee)***.
Theme 2: The influence of using mHealth tool during TB treatment		
Codes	**Subthemes**	**Sample quote**
Importance of completing TB treatment	TB treatment is lifesaving Taking treatment reduces TB transmission	*Because I was sick, and I wanted to live* ***(Non-adherent Female participant, Sunshine)***. *Eh, sister, it's very important to finish your medication because we live with other people sister. You are not living by yourself, some are involved with you, and you see that their lives are at risk, and there are children and older people mixed up in all this* ***(Adherent Male Participant, Owen)***
Consequences of not completing TB treatment	A major consequence of not taking TB treatment is death	*So now I knew that TB would kill me if I don't want it to kill me, but you don't want to die* ***(Adherent Male Participant, Owen)***.
Reminder messages useful	Feedback reminders encouraged medication intake	*They have helped me my sister, even though sometimes I would miss the time, I would still take the medication"****(Non-adherent Male participant, Bruce)***.

Theme 2: The influence of using mHealth tool during TB treatment		
Codes	**Subthemes**	**Sample quote**
Absent reminder messages -would you have taken pills on that day	Mixed reactions over taking treatment in the absence of feedback reminders	*Yeah, I would remember but not on time...* ***(Adherent Male Participant, Billy)***. *I did not see myself taking medication* ***(Adherent Female participant, Tee)***.
Motivation from the pillbox to attend clinic follow-up visits	mHealth technology motivated participants to attend scheduled follow-up visits	*Yes, and I have never missed [clinic visit], and to prove that I'm afraid of TB* ***(Adherent Female participant, Mama Gee)***.
Theme 3: Stigma and self-efficacy		
Codes	**Subthemes**	**Sample quote**
Feelings of embarrassment because of TB	Having TB is not an embarrassment	*No, they must know that's this thing exists, and it is curable… to tell the truth, I have never felt embarrassed* ***(Non-adherent Male participant, Bruce)***.
People's treatment after your TB diagnosis	Negative treatment from others due to the TB illness	*Oh, others thought of something else like HIV, what, what, they thought, they had in their minds, they didn't even think of TB, yeah* ***(Non-adherent Female participant, Lilly)***.
Theme 3: Stigma and self-efficacy		
Codes	**Subthemes**	**Sample quote**
Confident on completing TB treatment at the start of treatment	Self-confidence is key towards completing TB treatment	*Yeah, sister what motivated me the most, there are so many people medication, I'm not the only one…I would tell myself that I won't be defeated by someone who takes their medication until the die. I can't fail in 6 months, yeah* ***(Adherent Male Participant, Billy)***.
Reasons for staying adherent to TB medication over time	Knowledge of TB being curable made participants stay adherent	*I know that it can be cured* ***(Adherent Male participant, Jabu)***.
Reasons for not staying adherent to TB medication over time	Various individual reasons for not remaining adherent to treatment	*I forget everything… Yah you are rushing to go to work...medication can wait it happens* ***(Adherent Male participant, Jabu)***.
Theme 4: Sustainability of using the mHealth tool		
Codes	**Subthemes**	**Sample quote**
Value of using wisepill box in everyday life	It was part of my life	*No, it fitted perfectly sister you know, I never had a problem because in the end it was helping me to overcome my problems of not taking my medication… To never forget to take my pills on time on any day, Now I love it* ***(Adherent Male Participant, Owen)***.
Involvement in own healthcare before and after using the pill box	It was part of my life	*Before the box it was difficult* ***(Non-adherent Male participant, Mpilo)***.
Feelings of empowerment when using the pill box	Pill box empowered participants to keep moving	*Every time I say this baby was a hope each and every day there was a hope then it pushed me and then till now* ***(Adherent Female participant, Tee)***

Theme 4: Sustainability of using the mHealth tool		
Codes	**Subthemes**	**Sample quote**
Suggestions to personalise the pill box	Personalising the pill box	*I think, if it was possible, just that I don't know if it's possible though, I would want to be connected to my phone, more like a phone, so that I can change the ringtone, so you just go to the app ye pill box and change yeah… One thing I would change with the alarm maybe rather people have a choice of the music, choose the song you like… maybe I will add shelves because I had to cut some pills like strips, I will put maybe fours, and usually I would like to pack my wardrobe a be neat. So, I would just add shelves, yeah* ***(Non-adherent Female participant, Sunshine)***.
Barriers of using the pill box	A highlighted barrier of using the pill box is network connection issues	*Yes, and when it's about half an hour, then close it but when you close it same time it will ring the whole night… there was a time it did not ring properly and on time* ***(Adherent Female participant, Mama Gee)***.
Recommendation to use the device	Recommendation to use the pill box	*Yahh sister it's something that helped me, it will help them too, even if you sleep after you have forgotten, it will ring ti ti ti continue to ring until you remember to take your pills* ***(Non-adherent Male participant, Mpilo)***.

5.3 INTEGRATION OF QUANTITATIVE AND QUALITATIVE RESULTS: USING JOINT DISPLAYS

The researcher derived four main findings from the quantitative data analysis. The qualitative results were added to elaborate on and interpret the findings from the quantitative phase. Joint displays were used to optimise the visual presentation of the integration of the quantitative and qualitative findings. The summaries of the integrated results are illustrated in Table 28 and Table 29 The weaving technique used to present main findings in the narrative form is presented as follows:

Main finding 1:
Supportive feedback reminders from wisepill technology does not increase adherence over time.

***Quantitative*:** Feedback reminders from wisepill technology did not increase adherence over time. Although there was a significant increase of adherence from visit 1 to visit 2 (rank-sum at visit 1 = 9700.5; rank-sum at visit 2=20407), (p =.002 two-tailed), the trend decreased from visit 2 to visit 6. Despite this decrease, the study observed a significant increase over time between visit 2 to visit 4 because the sum-rank scores were higher than the rank-sum score at visit 1. The Cochran-Armitage test indicated insignificant increase for visit 5 and visit 6 because the rank-sum scores were less than the rank-sum score from visit 1 (rank-sum at visit 5=11915.5), (p =.075 two-tailed) and at visit 6 (rank-sum=11214.0), (p =.0529 two-tailed).

***Qualitative*:** From the qualitative findings, patients reported that the feedback reminders encouraged medication intake. The participants appreciated the reminder SMS messages from the wisepill technology. They found the technology to be helpful in reminding them to take their TB medication and to keep them on track. *"Yes, it is very appropriate because most of people, they default"* (Adherent Female participant, Tee). There were mixed reactions over taking treatment in the absence of feedback reminders. While some patients believed that they would have taken the medication, others mentioned that they would not have done so. One patient who felt ashamed when she did not take medication was reminded by the wisepill technology to take her medication. If the pillbox reminders were not available, she would have forgotten to take the medication at the right time. "*Yeah, I would remember but not on time..."* (Adherent Male participant, Billy*). "I did not see myself taking medication"* (Adherent Female participant, Tee).

***Comparison and integration*:** Although at face value the quantitative and qualitative components seem to contradict each other, the findings were interpreted to highlight reasons behind the changes in pattern observed at each respective time point/phase of treatment. Thus, the input derived from the qualitative results expanded the study's understanding of the trend analysis and the Cochran-Armitage test, which were used to highlight significant increases in medication adherence (at visit 1 to 4) and insignificant increases (at visit 5 to 6). This ultimately led to the conclusion that supportive feedback reminders from wisepill technology did not increase adherence over the six months' duration of TB treatment. However, it reminded the patients to take their TB medication timely.

Main finding 2:
There was a statistically significant difference between wisepill technology scores and other subjective adherence scores.

***Quantitative*:** Overall, adherence scores from wisepill technology differed significantly from all subjective adherence scores (three-item adherence, patient self-reporting on completing all TB medications, and patient self-reporting on missed dose(s)). Using Kruskal-Wallis and Mann-Whitney Wilcoxon tests, the study found significant differences in patient self-reporting on completing all TB medications and patient self-reporting on missed dose(s) scores at all the visits ($P < 0.05$) respectively. For the three-item adherence measure (i.e., second item), the study found significant differences amongst all the scores at all the visits ($P < 0.05$). Scores from the third item, compared to the rate of wisepill intake, also differed significantly at visit 1, 2, 3, and 4 ($P < 0.05$) respectively. However, visit 5 and visit 6 had insignificant differences ($P > 0.05$).

***Qualitative*:** The participants were knowledgeable about the consequences of not taking TB treatment. This knowledge motivated them to strive to adhere to taking treatment and ultimately complete their treatment. *"So, now I knew that TB would kill me. If I don't want it to kill me, but you don't want to die"* (Adherent Male participant, Owen). There were, however, individual reasons that were identified for not remaining adherent to treatment. One participant mentioned the following: *"Mhm, then maybe you starting … eish … to start to think negatively about the pills, that maybe they are the ones giving me a headache"* (Adherent Male participant, Jabu).

***Comparison or integration*:** Study patients who used wisepill technology self-reported high adherence. However, when testing their self-reported information against the rate of wisepill intake scores, the study found major variation between the two measures of adherence at all the recorded visits. Kruskal-Wallis and Mann-Whitney Wilcoxon tests determined that there was a statistically significant difference in subjective adherence scores from patients' self-reports on completing treatment and not missing a dose versus the rate of wisepill intake ($P < 0.05$ at all 6 visits). Qualitative findings revealed that although participants knew about the consequences of not taking TB treatment, this did not automatically translate into participants' following the treatment. Multiple reasons were identified that contributed to participants' not remaining adherent to TB treatment. In this context, it may have been that participants provided responses that corresponds with the way the researcher wants them to be responded, rather than respond naturally (i.e. response bias). In addition, being knowledgeable about TB and knowing the purpose of the study may have influenced the participants' responses. The latter expanded the study's understanding of why it observed the difference between wisepill technology scores and other subjective adherence scores. The aforementioned statistical difference therefore demonstrates the difference between self-report measures of adherence and other subjective measures of adherence.

Main finding 3:
Adherence scores from wisepill technology predicted overall TB treatment outcomes.

Quantitative: The study's findings revealed that patients who were adherent (scored 80% and above), according to wisepill technology (OR 3.93; 95% CI 1.95, 5.91; $p = 0.001$), were 3.93 times more likely to have successful TB outcomes compared to those who were non-adherent (scored less than 80%). Therefore, adherence to TB treatment from wisepill technology was significantly associated with overall TB treatment outcome.

Qualitative: The wisepill technology was part of the participants' lives. It had value and was seen as a companion. The wisepill box reminded them to take their medication. One participant said the following: *"It reminds me of my life … Yes, it gave me life" (*Adherent Female participant, Mama

Gee); *"Yeah, to, every time when I saw it, I saw that, okay, I am comforted to drink, you will be alright… Yes, it was more like a friend"* (Non-adherent Female participant, Sunshine).

***Comparison or integration*:** Using the bivariate logistic regression model, the study was able to ascertain that adherence scores from wisepill technology predicted overall TB treatment outcomes. Qualitative findings supported the results obtained, with participants confirming that wisepill technology was integrated in their lives as a companion and was there to support their medication intake.

Main finding 4:
Stigma and self-efficacy predicted overall TB treatment outcomes even when reminders from wisepill technology are added.

Quantitative: The study found that stigma (both internalised and enacted) and self-efficacy predicted TB treatment outcomes even when reminders from wisepill technology were added. There was a significant association between internalised stigma and TB treatment outcomes (OR 2.61; 95% CI 1.30, 5.23; p = 0.007) with a low negative association between the variables, lower levels of internalised stigma experienced by patients was associated with high levels of TB treatment outcomes. Similarly, enacted stigma was significantly associated with TB treatment outcome (OR 2.91; 95% CI 1.28, 6.62; p = 0.011), with a low negative association between the variables in that lower levels of enacted stigma experienced by patients were associated with higher levels of TB treatment outcomes. A significant association was observed between extreme self-efficacy experience and overall TB treatment outcome (OR 1.63; 95% CI 1.39, 1.92; p = 0.001).

***Qualitative*:** Most of the participants in the study mentioned that having TB was not an embarrassment for them, despite receiving some negative treatment from others owing to this illness. One participant specifically mentioned being misdiagnosed by people, with them saying that he had AIDS or the coronavirus. However, participants knew that they would become healthy if they took their medication as prescribed. Self-confidence was their key to completing their TB treatment. The following was said: *" No, they must know that'(s) this thing exists, and it is curable … to tell the truth, I have never felt embarrassed"* (Non-adherent Male participant, Bruce). *"Yeah, sister, what motivated me the most, there are so many people on medication, I'm not the only one … I would tell myself that I won't be defeated by someone who takes their medication until they die. I can't fail in six months, yeah"* (Adherent Male participant, Billy).

***Comparison or integration*:** Using the bivariate logistic regression model, the study was able to ascertain that both stigma and self-efficacy predicted overall TB treatment outcomes even when

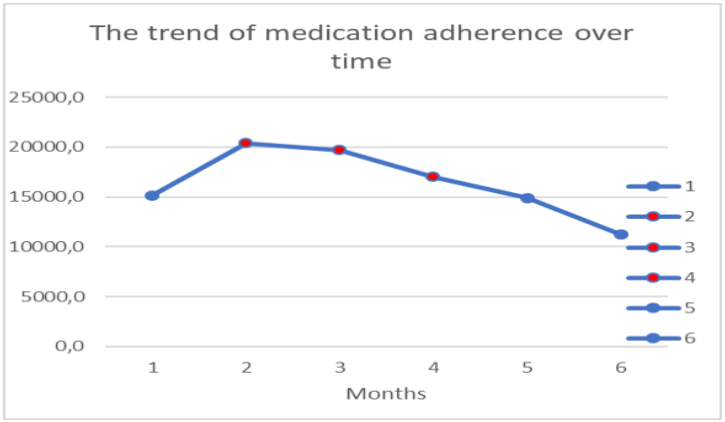
reminders from wisepill technology were added. Patients who participated in the study were more likely to have successful treatment outcomes when they experienced low internal stigma, low enacted stigma, and identified with higher self-efficacy compared to fair levels of or not having self-efficacy. Qualitative findings expanded on the results observed, that patients who experienced low levels of stigma and high levels of self-efficacy were more likely to have favourable TB treatment outcomes.

Table 28:
Summary Table Highlighting Major Findings from Integrated Quantitative and Qualitative Data Developed by Author in January 2023

Joint display of the integrated quantitative and qualitative data	Outcomes
Main finding 1: Supportive feedback reminders from wisepill technology does not increase adherence over time. • A significant increase of adherence was observed from visit 1 to visit 2 (rank-sum at visit 1 = 9700.5; rank-sum at visit 2=20407; *p*=.002 two-tailed) and between visit 2 to visit 4 (i.e., the sum-rank scores were higher than rank-sum score at visit 1). *…Yes, it is very appropriate because most of people they default (Adherent Female participant, Tee).* • Insignificant increase for visit 5 (Rank-sum at visit 5=11915.5, *p* =.075 two-tailed) and visit 6 (Rank-sum=11214.0, *p* =.0529 two-tailed) was also observed because the rank-sum scores were less than the rank-sum score from visit 1. *…I did not see myself taking medication" (Adherent Female participant, Tee).."Yeah, I would remember but not on time... (Adherent Male Participant, Billy).*	**Expansion**
Main finding 2: There was a statistically significant difference between wisepill technology scores and other subjective adherence scores. • Overall, adherence scores from wisepill technology compared to all subjective adherence scores [i.e., three-item adherence, Patient self-reporting on completing all TB medications, and Patient self-reporting on missed dose(s)] differed. • The study found significant differences (P <0.05) in patient self-reporting on completing all TB medications, in patient self-reporting on missed dose(s), in the three-item adherence measure (i.e., second item), and in the three-item adherence measure (i.e., third item at visit 1,2,3, and 4). *…So now I knew that TB would kill me. If I don't want it to kill me, but you don't want to die (Adherent Male Participant, Owen)* *…Mhm then maybe you starting eish to start to think negatively about the pills that maybe they are the ones giving me a headache (Adherent Male participant, Jabu).*	**Confirmation & Expansion**
Main finding 3: Adherence scores from wisepill technology predicted overall TB treatment outcomes. • Adherence to TB treatment from wisepill technology was significantly associated with overall TB treatment outcome. • Adherent patients (i.e., scored 80% and above) according to wisepill technology (OR 3.93; 95% CI 1.95, 5.91; p = 0.001) were 3.93 times more likely to have successful TB outcomes compared to those who were non-adherent (i.e., scored less than 80%). *...It reminds me of my life… Yes, it gave me life (Adherent Female participant, Mama Gee);"* *Yeah, to, every time when I saw it, I saw that okay I am comforted that drink, you will be alright… Yes, it was more like a friend (Non-adherent Female participant, Sunshine); Before the box it was difficult (Non-adherent Male participant, Mpilo).*	**Confirmation**

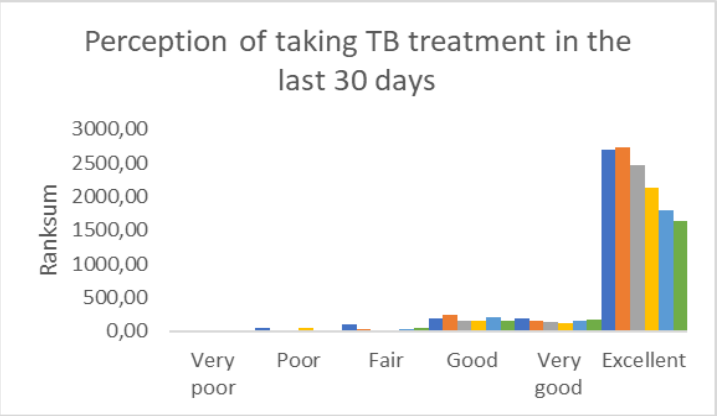
Joint display of the integrated quantitative and qualitative data	Outcomes
Main finding 4: Stigma and self-efficacy predicted overall TB treatment outcomes even when reminders from wisepill technology are added. • Stigma (both internalised and enacted) and self-efficacy predicted successful TB treatment outcomes even when reminders from wisepill technology are added. • There was a significant association between stigma and TB treatment outcomes; internalised stigma (OR 2.61; 95% CI 1.30, 5.23; p =0.007) and enacted stigma (OR 2.91; 95% CI 1.28, 6.62; p =0.011). • A significant association was observed between extreme self-efficacy experience and overall TB treatment outcome (OR 1.63; 95% CI 1.39, 1.92; p =0.001). *...No, they must know that's this thing exists, and it is curable… to tell the truth, I have never felt embarrassed (Non-adherent Male participant, Bruce); I still hear the bad mouth… Yah they will be not comfortable around you. So that's the reason, they say ahh I have AIDS… Things like Corona (Adherent Male participant, Jabu). Yeah, sister what motivated me the most, there are so many people on medication, I'm not the only one…I would tell myself that I won't be defeated by someone who takes their medication until they die. I can't fail in 6 months, yeah (Adherent Male Participant, Billy).*	**Confirmation**

Table 29:
Summary of Integrated Quantitative and Qualitative Results Using Joint Displays Developed by Author in January 2023

Understanding the usability of an mHealth tool to support medication adherence schedules in newly diagnosed TB patients		
Quantitative observations	**Qualitative themes and/quotes**	**Outcomes**
Main finding 1: Supportive feedback reminders from wisepill technology does not increase adherence over time.  There was a significant increase in adherence from visit 1 to visit 2. The trend decreased from visit 1 to visit 6, although it was not significant (p>0.05). A significant increase was observed for visit 2 to visit 4. An insignificant increase for visit 5 and visit 6 was observed (the rank-sum scores were smaller than the rank-sum score of visits 1). Gender differences between males and females were identified when comparing the decline in adherence. A steep decline was observed in females from visit 2 to visit 6 compared to males, whose decline in adherence was significant only at visit 6.	*Erh, it was useful because, uhm, it was like it didn't take, like, more than 30 minutes to remind you from your time of taking the pills so that you can still take the medication* **(Adherent Male participant, Jabu).** *As I said to you, the container was in the kitchen, so every time I felt hungry, I would go to the kitchen, then even if the reminder wasn't there, I would remember by seeing the container ... Yes, so if the container wasn't there, then I wouldn't remember that I have to take my meds ...* **(Non-adherent Female participant, Lilly)**.	**Expansion**

Understanding the usability of an mHealth tool to support medication adherence schedules in newly diagnosed TB patients		
Quantitative observations	**Qualitative themes and/quotes**	**Outcomes**

Main finding 2: There was a statistically significant difference between wisepill technology scores and other subjective adherence scores.



Participants in the study who used wisepill technology self-reported high adherence, although, when testing their self-reported information against the rate of wisepill intake scores, the study found great variation between the two measures of adherence in most, if not all, recorded visits.

So now I knew that TB would kill me if I don't want it to kill me, but you don't want to die **(Adherent Male participant, Owen).**

... I wanted to make sure that I achieve a goal, neh, to finish my medication so that I can feel better... **(Non-adherent Female participant, Lilly)**

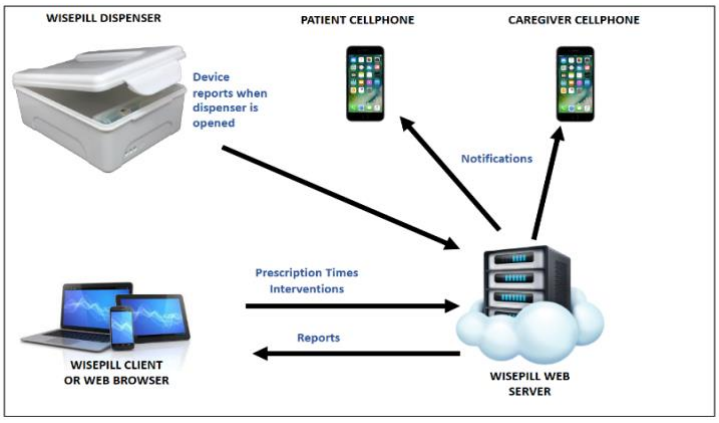
I forget everything ... Yah, you are rushing to go to work...medication can wait it happens **(Adherent Male participant, Jabu)**

...and then, when you count the pills that you have to take and they become a lot, it bothers me **(Adherent Female participant, Mama Gee).**

Confirmation & Expansion

Main finding 3: Adherence scores from wisepill technology predicted overall TB treatment outcomes.

The study's findings revealed that patients who were adherent (compliant) according to wisepill technology **(OR 3.93; 95% CI 1.95, 5.91; p < 0.05)** were **3.93** times more likely to have successful TB outcomes compared to those who were non-adherent (noncompliant). Adherence to TB treatment from wisepill technology was significantly associated with overall TB treatment outcome.

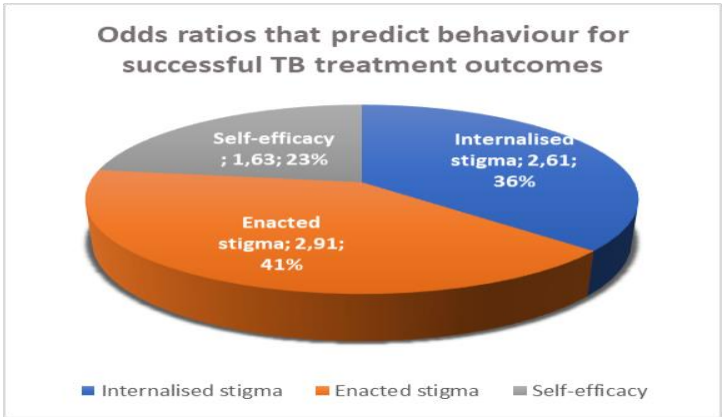


It represent my health that I have to be motivated to take my treatment on time… **(Adherent Male participant, Billy)**.

… it rings, I'm going to take my pills. I didn't hide those pills … I took it everywhere … everywhere I go. It was part of my life **(Adherent Female participant, Tee).**

No, it fitted perfectly, sister. You know, I never had a problem because in the end it was helping me to overcome my problems of not taking my medication … To never forget to take my pills on time on any day. Now I love it **(Adherent Male participant, Owen)**

Confirmation

Understanding the usability of an mHealth tool to support medication adherence schedules in newly diagnosed TB patients		
Quantitative observations	**Qualitative themes and/quotes**	**Outcomes**
Main finding 4: Stigma and self-efficacy predicted overall TB treatment outcomes even when reminders from wisepill technology are added.  There was a significant association between internalised stigma and TB treatment outcomes **(OR 2.61; 95% CI 1.30, 5.23; p = 0.007).** Enacted stigma was also significantly associated with TB treatment outcome **(OR 2.91; 95% CI 1.28, 6.62; p = 0.011).** A significant association was observed between extreme self-efficacy experience and overall TB treatment outcome **(OR 1.63; 95% CI 1.39, 1.92; p =0.001)**.	*No sister I was not feeling embarrassed at all because I had told those who I live with. It's just that there are a lot of people with TB, and they don't know that they have TB … I can be able to be on treatment. Instead of being killed by something that you did not even know you had, you see … it's better to know your status* **(Adherent Male participant, Owen)** *I just told them I have TB and whoever decided to visit, visited; others stopped coming, they are no longer visiting me, and I just decided to carry on with my life* **(Non-adherent Male participant, Bruce)** *And then I didn't hesitate to take my medication* **(Adherent Male participant, Jabu)** *Eish, all I wanted was to be cured* **(Non-adherent Male participant, Bruce)**	**Confirmation**

5.4 CONCLUSION

The results outlined in this chapter were organised around the quantitative and qualitative research aims of this study to determine the influence of mHealth feedback reminders on TB patients' medication adherence, given the effect of stigma and self-efficacy on adherence.

The researcher derived four main findings from the quantitative data analysis, which she integrated with the qualitative results to highlight whether they expanded and/or confirmed what was observed. The findings were as follows:

- Supportive feedback reminders from wisepill technology did not increase adherence over time;
- There was a statistically significant difference between wisepill technology scores and other subjective adherence scores;
- Adherence scores from wisepill technology predicted overall TB treatment outcomes; and

- Stigma and self-efficacy predicted overall TB treatment outcomes even when reminders from wisepill technology were added.

The findings are discussed in relation to extant literature in Chapter 6, along with the limitations of the present study and recommendations for future research.

CHAPTER 6: DISCUSSION OF STUDY FINDINGS

In this chapter the findings are collated and presented in the context of existing literature. The first section offers an overview of the findings in relation to previous research. The findings are also interpreted from the perspective of pragmatism and the health belief model. The chapter concludes with an overview of the study's limitations and recommendations as well as an indication of the significance of the research.

6.1 USABILITY OF AN MHEALTH TOOL IN SUPPORTING MEDICATION ADHERENCE

Using a mixed-methods research approach enhanced the validity of the study's results (Creswell, 2014; 2015; Creswell & Creswell, 2017; Johnson & Onwuegbuzie, 2004). Incorporating both quantitative and qualitative data contributed to a more detailed understanding of the value of using an mHealth tool in the treatment of TB. The researcher compared the results of the study with those of previous studies to contextualise the importance of the research.

6.1.1 Supportive Feedback Reminders From Wisepill Technology do not Increase Adherence Over Time

The study concluded that supportive feedback reminders from wisepill technology does not increase adherence over the six months' TB treatment duration. This conclusion was supported by explanations derived from the qualitative results, which expanded the study's understanding of the trend analysis and Cochran-Armitage test, which indicated a downward trend in medication adherence from visit 2 to visit 6. A meta-analysis study of 11 projects across 10 high tuberculosis-burdened countries, including South Africa, on the time-trend analysis of TB treatment, using digital adherence technologies, reported similar trends. The proportion of DS-TB patients with ≥90% adherence declined from 79.9% in month 1 to 70.8% in month 6, signifying a decrease in adherence over time (de Groot et al., 2022).

In this study, significant increases between visit 1 and visit 4 were observed, but they were followed by a decrease at visit 5 and visit 6. It has been argued that patients tend to have lower adherence in their continuation phase (last four months) of treatment compared to the intensive phase (first two months) as they feel that they are getting better. Therefore, the TB treatment phase has an influence on adherence (Mekonnen & Azagew, 2018; Stagg et al., 2020). Gashu et al. (2021) argue that the continuation phase of TB treatment is mainly patient-centred and daily medication-taking is supposed to be supported by the community (family, relatives, neighbours, and community health workers).

Essentially, the use of the pillbox technology strengthens participants' adherence, but it does not change adherence patterns linked to the stage of illness. The six months' treatment duration was supported by the pillbox, which functioned as a reminder and a motivator for participants to take their medication. Participants mentioned that the pillbox motivated them to follow up on their scheduled clinic visits. Similar findings were shared by Musiimenta et al. (2023), that wisepill was useful in reminding and motivating participants to take their medication. In addition, using real-time adherence monitoring linked to SMS reminders creates the potential for intervening prior to the development of treatment failure and/or drug resistance (Musiimenta et al., 2023). However, in this study, participants had mixed feelings regarding taking the medication if the reminders were absent. In the end, the pillbox helped participants to keep taking their medication on time, as prescribed. There were no differences between the adherent and non-adherent patients in terms of their attitudes towards using the pillbox.

Other potential reasons for the decrease in adherence over time includes patients who suffer side effects (which may result in treatment discontinuation), or inversely, they experience fewer symptoms during the continuous phase and interpret this as their being cured (El-Muttalut & Khidir Elnimeiri, 2017; Gashu et al., 2021; Nour El Din et al., 2013). This results in patients becoming less eager to take medication. Illness cognitions play an influential role in participants' personal theories about the duration of the treatment and experiencing symptoms. The Alhazami et al. (2020) and Do et al. (2019) studies demonstrate that the novelty of the digital technology diminishes for patients. For example, in the beginning, patients are comfortable with using the digital technology (as they can use it better); however, thereafter the usually observed adherence pattern occurs, namely a decrease in adherence from the intensive phase to the continuation phase (Alhazami et al., 2020; Do et al., 2019).

Disengagement from the technology does not necessarily reflect suboptimal medication intake (Drabarek et al., 2019; Haberer & Subbaraman, 2020; Mohammed et al., 2012; Mohammed et al., 2016). Primarily, the pattern of TB treatment and adherence influences medication use. Additional reasons for a decline in adherence, despite using the wisepill technology, include participants not being confident at the beginning of treatment that they will be able to take the treatment for six months, forgetfulness, being busy, living alone, having no family support, and the pill burden from taking other chronic medication in addition to pills for TB. Gashu et al. (2021) mentioned travelling away from home without pills as major reasons for non-adherence to TB treatment. However, this contrasts the study findings, in that participants who usually travelled away from home to visit their families carried the pillboxes along with them. Therefore, wisepill technology was useful to "rectify" some issues that could decrease medication intake over time (forgetfulness). A qualitative study conducted with patients and healthcare providers from India relating to differences in the acceptability of 99DOTS, a cell phone-based strategy for monitoring adherence to TB medications, found that SMS text messaging

reminders encouraged the habit of pill-taking and improved family involvement in TB care (Thomas et al., 2021).

In this study the decline in adherence, identified when the data was stratified by gender, indicated that the female trend illustrated a steep decrease in adherence from visit 2 to visit 6. The male trend indicated a significant decrease in adherence only at visit 6. This finding demonstrates that there are gender differences in digital health use – a pattern related to the technology use in this case. However, these differences are not only complex and multifactorial, but also context dependent. It is therefore important to understand the reasons that the study observed different trends between males and females in TB medication adherence over time when using digital adherence technologies. This information will help in the overall development of technologies (Goswami & Dutta, 2015). This study did not explore this interesting finding; however, future research should explore gender differences in using digital health tools specific to this context.

In relation to exploring gender differences, Liu et al. (2023) emphasised the need to better understand adherence patterns with using technology to improve the implementation of differentiated care. De Groot et al. (2022) showed results that were inconsistent with those found in this research study, in that DS-TB male patients showed lower adherence and a steeper decrease over time compared to females, a difference that was statistically significant (de Groot et al., 2022). Therefore, it is evident that this difference may be attributed to males being more likely to engage in risky behaviours, such as alcohol abuse, drug use, and smoking, which are often associated with lower adherence (Ogundele et al., 2016; Stop TB Partnership, 2021; Tola et al., 2017). In addition, Goswami and Dutta (2015) reviewed a study on technology usage and the intention to use technology from a gender perspective and found that gender is an influencing factor in technology adoption. Men were found to be more technologically adept compared to women, in the context of information technology (IT), which included computers, email services, and electronic data management systems (Goswami & Dutta, 2015). The authors, however, cautioned that there were mixed results with respect to the influence of gender on technology adoption.

In a few contexts, gender played a significant role in determining the intention of accepting new technology, although there were cases when gender differences were not observed (Goswami & Dutta, 2015). Understanding the reasons for gender differences in using new technologies is important for the adoption and overall development of technologies. The time-trend analysis presented in this study not only provides valuable insights, but demonstrates the complex, dynamic, and longitudinal patterns related to TB medication adherence among newly diagnosed TB patient on six months' treatment.

6.1.2 Statistically Significant Difference Between Wisepill Technology Scores and Other Subjective Adherence Scores

This study reported variations that occurred between wisepill technology scores and other subjective adherence scores. In comparison to the rate of wisepill intake, self-reported medication adherence was high and statistically significant for completing treatment and not missing a dose. As found in other studies, self-reported adherence is usually higher compared to measures from electronic monitoring technologies (Arnsten et al., 2001; Gaifer & Boulassel, 2019; Orrell et al., 2017; Usitalo et al., 2014) because patients overestimate adherence, possibly owing to social desirability bias and recall biases (Castillo-Mancilla & Haberer, 2018; Koss et al., 2018).

In addition, findings from a study conducted in Uganda on monitoring adherence to antiretroviral therapy among adolescents (N=702), comparing wisepill to self-reporting in predicting viral suppression in a cluster-randomised trial, found that wisepill indicated 79.2% of the participants had good ART adherence, while self-reporting on good adherence indicated 97.0% (Kizito et al., 2022). There was 77.7% agreement between self-reporting and wisepill usage when monitoring adherence. However, the observed agreement between self-reporting versus viral load and wisepill versus viral load was lower (64.0% and 61.4%, respectively). This suggests that, although self-reporting and the wisepill measure on adherence showed significant agreement, neither is an accurate predictor of virological outcome (Kizito et al., 2022). Self-reported adherence was found to be significantly higher in males than in females (Kizito et al., 2022).

Qualitative findings in this research provided multiple reasons for the high self-reporting found compared to the wisepill measure from the quantitative findings, which expanded our understanding of why these differences were observed. It is not unusual to find self-reports overestimating actual adherence (Oates et al., 2019). Subjective measures, although they are easier to collect, are subject to information bias or recall bias, resulting in inadequate reliability and overestimation of adherence (Collaco et al., 2012). It is argued that objective and self-reported adherence tap different behavioural constructs and measure different phenomena (Jerant et al., 2008). Self-reports essentially measure the perception of adherence and reflect on a perceived sense of control (Cecere et al., 2012), self-esteem and self-efficacy as well as on knowledge about the prescribed treatment regimen (Modi & Quittner, 2006). A study by Subbaraman et al. (2021) evaluated multiple tuberculosis adherence measures that were compared against an objective urine isoniazid metabolite testing. The idea was to measure whether medication had been taken. The alternative adherence measures comprised 99DOTS (a cell phone-based DAT), a pill estimate, four-day dose recall, and a question assessing the time of the last missed dose. A single, unannounced home visit was undertaken to each participant, during which time a urine sample was collected to be tested for INH metabolites. The study found that alternate measures

missed detecting at least 30% of people who were non-adherent through urine testing. Therefore, TB programmes need to evaluate the feasibility of integrating more accurate, objective measures with routine care, such as urine testing, including pillbox estimates (Subbaraman et al., 2021).

Generally, a complex interplay exists between objective and subjective measures for medication adherence. Reasons for non-adherence should not only be based on personal believes, but also factor in the influence of social factors outside the patient's own control (i.e., forgetfulness and misunderstandings) (George et al., 2016). In the context of this study, possible reasons for the differences observed were similar to those found in the study by Kizito et al. (2022), which includes participants taking their TB medication without using the wisepill device, resulting in misclassification bias in adherence. In addition, the technical challenges such as interruptions in signal transmission and failure to send a signal due to power outages and drained batteries resulted in missing data in measuring adherence (Kizito et al., 2022).

6.3.3 Adherence Scores From Wisepill Technology Predicted Overall TB Treatment Outcomes

This study's findings determined that adherence scores derived from wisepill technology predicted overall TB treatment outcomes. Patients who were categorised by wisepill as adherent were 3.93 times more likely to have favourable TB treatment outcomes compared to non-adherent patients. Wisepill technology formed part of the participants' lives through assisting them in their health management. The technology assisted participants in being organised and consistent about taking their TB medication on time. Furthermore, it provided support during their treatment journey which, as a result, promoted patient-centred care approach. Mukora et al. (2023) conducted 62 in-depth interviews with participants in local languages across three provinces in South Africa to understand acceptability of using the pillbox and the experience of a differentiated care approach for TB treatment adherence among people living with TB. The findings suggest that participants had a positive attitude towards the pillbox. They appreciated the reminders and were keen to live a healthier life (Mukora et al., 2023). Similar findings were reported from a study conducted in Uganda by Musiimenta et al. (2019). The researchers reported that wisepill technology was acceptable to the participants and they felt that being monitored enabled them to prove their commitment to adhering to treatment (Musiimenta et al., 2019). Literature (Manyazewal et al., 2023; Thomas et al., 2021; Wang et al., 2020) suggests that participants report usability and satisfaction with using the electronic medication event reminder and monitoring device (wisepill technology). Manyazewal et al. (2023) reported a significantly higher number of users likely to promote the device. Pillboxes have the potential to transform patient-centred care through ongoing evaluation and scaling up digital health innovations. In addition, Manyazewal et al. (2023) found a positive association between treatment satisfaction and medication adherence.

Although the reminder messages from the wisepill technology benefits end users with the provision of a support system that enables them to make a habit of taking their medication as scheduled, Lester et al. (2019) cautioned against people receiving one-way messages without an opportunity to respond. It needs to be kept in mind that people may feel undermined or annoyed by the frequency of reminders, and may potentially ignore these messages (Bardosh et al., 2017). The use of digital adherence technology in high-burden TB countries is critical and requires more effort from the technologies not only as regards their adaptation to them but also to ensure that they meet the needs and desires of users (Drabarek et al., 2019; Musiimenta et al., 2019; Thekkur et al., 2019; Thomas et al., 2020a; 2020b; Wang et al., 2019).

In this study, some participants experienced challenges with the technology malfunctioning owing to network and connectivity issues. Nonetheless, they recommend the use of the wisepill technology. Issues of network coverage (especially when there is no electricity), with difficulties accessing Wi-Fi or the internet, and technical issues with the digital adherence technology platforms have been reported in literature (Ames et al., 1996; Guzman et al., 2023). The challenges identified in the study were similar to those in a study conducted by Leddy et al. (2023) in Uganda on barriers and facilitators to implementing a digital adherence technology for TB treatment supervision in relation to network issues. The barriers highlighted by Leddy et al. (2023) during the implementation related to participants' experiencing limited access to electricity to charge their mobile phones to make dosing confirmation calls, and poor network connection. In addition, a study by Haberer et al. (2022) reported that the technological monitor and daily SMS generally functioned well, although excess SMSs were triggered, primarily owing to cellular network delays (Haberer et al., 2022). Mukora et al. (2023) reported that participants felt burdened by the idea of moving around with the device because of its size and the alarm, which could lead to disclosure of their TB status. In the study of Thomas et al. (2021) among multidrug-resistant TB patients (MDR-TB) in India, the issue of the large size of the pillbox resulted in lower acceptance of the technology. Therefore, participants chose to remove the medication from their device to avoid any stigma and discrimination (Thomas et al., 2021). It is therefore important to consider the recommendations the end users suggested for improving the design of the technology. After all, the success of a health technology intervention is dependent on the end user's satisfaction with and the usability of the technology because it is designed to benefit their health and well-being (Lester et al., 2019).

This study confirmed that adherence to TB treatment from wisepill technology was significantly associated with overall TB treatment outcomes. This was also concluded in a clinical trial study conducted by Acosta et al. (2022) in Peru on a real-time medication event reminder monitor in relation to the treatment outcomes. The study by Acosta et al. (2022) found improved successful

treatment outcomes among patients who had a real-time medication event reminder monitor versus those who received standard care. However, an inverse effect on the relationship between digital adherence technologies on TB treatment outcomes was also reported by Yoeli et al. (2019), who conducted a random trial in Kenya. The study observed that when using SMS reminders and an unstructured supplementary service data intervention, there was a reduction in poor outcomes (on treatment death, loss to follow up, or treatment failure) (Yoeli et al., 2019).

6.3.4 Stigma and Self-efficacy Predicted Overall TB Treatment Outcomes Even When Reminders From Wisepill Technology are Added

The study showed that both stigma and self-efficacy predicted overall TB treatment outcomes even when reminders from wisepill technology were added. Patients who experienced low levels of internalised and enacted stigma were 2.5 times more likely to have favourable TB treatment outcomes, compared to those who experienced high internalised and enacted stigma. The qualitative findings supported these quantitative results, that participants who experienced low levels of stigma and high levels of self-efficacy were more likely to have favourable TB treatment outcomes.

Studies in South Africa and Zambia confirm that internalised stigma is marked by low self-worth and that anticipated stigma impacts disclosure of a person's status owing to the fear of negative reactions (Cremers et al., 2015; Murray et al., 2013). In a scoping review of health-related stigma outcomes for high-burden diseases in low- and middle-income countries, Kane et al. (2019) found similar results. High stigma was associated with decreased medication adherence. A study conducted by Abdisa et al. (2020) on self-stigma and medication adherence among patients with mental illness treated at the Jimma University Medical Center in southwest Ethiopia, found that self-stigma was a contributing factor to non-adherence to medication which results in increased healthcare costs (Abdisa et al., 2020).

In relation to using the wisepill technology, it has been found by Cross and colleagues (2019) that other digital adherence tools, such as 99DOTS, offer a potentially less stigmatising opportunity for patients to take their medication discretely and privately compared to the pillbox (Cross et al., 2019). In addition, this led to a potential explanation for the lower adherence observed in their projects using wisepill technology, as stigma can influence treatment adherence negatively (Craig et al., 2017). Stigma can disrupt patients' social interactions with others, reduce general social functioning, and the ability to fulfil daily roles. This ultimately endangers the patients' quality of life (Chen et al., 2021).

Most of the participants in this study experienced low internalised and enacted stigma. This was evident when they expressed not being embarrassed by their TB-diagnosis status nor by

internalising community stigma, when some people avoided them for fear of being infected and bad-mouthed them about their illness. Tuberculosis was perceived by participants as curable, and they wanted to get better and live a happy/normal/fulfilling life. Community-induced stigma was, however, perceived as a barrier to medication adherence. Therefore, personal health threat was a priority to participants; hence, they did not internalise community stigma. In addressing this threat, they diverted their attention to taking their TB treatment. According to LaMorte (2022), variations in a person's feelings regarding barriers often lead to a cost/benefit analysis.

Although the sample in this study was specifically selected not to include patients who have HIV so as to avoid the additional stigma these patients may experience, the qualitative findings indicated participants mentioning that people around them thought they were infected with HIV when, in fact, they were taking their TB treatment. Therefore, the association with HIV also increases TB stigma. Tuberculosis stigma is prevalent, and a recent South African study conducted across three districts (Ekurhuleni, Gauteng; Bojanala, North West; and uMkhanyakude, KwaZulu-Natal) found that the presence of TB stigmatisation is driven by the fear of the TB disease. The stigmatisation manifests as anticipated and internalised stigma (DeSanto et al., 2023). DeSanto et al. (2023) state that people are marked with the TB stigma verbally through gossip and visually through symptomatic identification or when accessing care at clinics (in TB-specific areas) or through ward-based outreach teams. Therefore, patients' unique understanding of stigma will influence how they seek care (DeSanto et al., 2023). Regarding the fear of TB infection or transmission, DeSanto et al. (2023) found that both fear of infection and transmission were important drivers in facilitating TB stigma. It is therefore important for community members who often voice their concern about transmission to understand that, once the patient is on treatment, they are no longer able to transmit TB (DeSanto et al., 2023). Individuals who are ill should consequently be guided to understand the importance and need for adherence to their medication (Okuboyejo et al., 2018).

In addition, the current study also demonstrates that self-efficacy predicted successful treatment outcomes. Study participants who reported self-efficacy in taking medication despite varying situations were 1.63 times more likely to have favourable TB treatment outcomes, compared to participants who had rated themselves fairly or who were not confident in their responses. The study's findings are supported by research (Azizi et al., 2018; Gebremariam et al., 2021), which found that self-efficacy was the most important determinant of medication adherence among pulmonary TB patients. Martono et al. (2023) support the latter findings and mention that they might be related to patients' self-confidence, meaning that self-confidence affected patients' cognitive processes, enabling them to make quality decisions, set practical goals, and make plans to overcome obstacles and challenges in taking their TB medication (Martono et al., 2023). Self-efficacy is a significant predictor

of healthy behaviour adherence (Al Hashmi & Al Omari, 2022). Therefore, it is evident that medication adherence behaviour is related to self-efficacy (Okuboyejo et al., 2018).

Self-efficacy in the study was important among the participants because it encouraged them to take their TB treatment because they would be cured if they did so. According to Okuboyejo et al. (2018), the confidence someone has in their ability to perform an action (self-efficacy) and the expectation that the behaviour would have a desirable result (outcome expectations) are important mediators of performance in medication adherence behaviour (Okuboyejo et al., 2018). In addition, individuals with high self-efficacy are said to be resilient and would persist in the face of setbacks (Martono et al., 2023). Primarily, patients with high self-efficacy are more likely to comply with taking their medication (Amer et al., 2018). It is therefore important to develop and implement targeted interventions to improve patients' self-efficacy (Shen et al., 2020). Studies have shown that self-efficacy can contribute significantly to patients' disease management behaviours, such as adhering to medication (Náfrádi et al., 2017), seeking support (Williams & Takaku, 2011), limiting risk behaviours (Mahat et al., 2016), and obtaining better health outcomes through these specific behaviours (Wang et al., 2017). In contrast to the study's research findings, a study conducted by Gebremariam (2021) on the determinants of adherence to anti-TB treatment and associated factors among adult TB patients in the Gondar city administration, northwest Ethiopia, showed that TB patients with high perceived self-efficacy were less likely to be adherent to anti-TB treatment. The explanation for this finding were summarised as follows: 1) high self-efficacy negatively affected people's motivation to do something that they had already adopted; 2) an individual's manifestation of high self-efficacy is characterised by a tendency to overestimate their performance and lack of trust in the diagnoses of treatments. Thus, patients with high perception towards anti-TB treatments in the continuation phase felt well because of improved clinical signs and symptoms that were subsiding (Gebremariam, 2021). However, findings in the study of Akbar et al. (2020) found that adult TB patients who had high self-stigma were three times more likely to have low self-efficacy of treatment compliance than adult TB patients who had low self-stigma.

6.2 FINDINGS ON THE PARADIGMATIC POSITION OF PRAGMATISM AND HEALTH BELIEF MODEL

Adherence to medication, especially for chronic conditions, is a learnt behaviour (Unni & Bae, 2022). In addition, Okuboyejo et al. (2018) recognise that adherence to medication is a complex behavioural issue, especially in respect of long-term therapy in an outpatient setting. Therefore, theories help to understand and conceptualise the problem, and to develop coherent interventions that increase transferability (Okuboyejo et al., 2018). The current study applied a mixed-methods approach that attempted to develop a comprehensive understanding of the phenomenon under investigation. A

mixed-methods design, informed by the pragmatic paradigm, is useful for effective investigation of complex health research conditions, where the goal rests with finding a practical solution to a research problem (Allemang et al., 2022). Using a pragmatic paradigm approach in this research justified and supported the use of mixed methods to determine the influence of mHealth feedback reminders on TB patients' medication adherence and to understand their experiences in using mHealth technologies. Furthermore, the researcher used the health belief model as the guiding principle to understand medication adherence among TB patients (their perceptions when it comes to making health-related decisions) (Azizi et al., 2018).

Similar to a qualitative scoping review that Kvarnström et al. (2021) conducted on factors contributing to medication adherence in patients with a chronic condition, this study found that patients who adhered strictly to their medication were those who perceived the threat of this health risk to be serious, that they were personally susceptible (they were infected), and that they would benefit from taking the prescribed medication. The patients took their medication to get healthy and to prevent transmitting the TB disease to their families or the people around them. In addition, it was highlighted that the consequence of not taking TB treatment was death or developing drug resistance. The patients wanted to live and be cured of TB, which were characteristic of the benefits that come with taking TB treatment. It is important to note that the choice to take or not to take TB medication may depend on how seriously the patient assesses their situation to be (Kvarnström et al., 2021).

Wisepill technology represented a cue to facilitate the action of taking treatment or is used to instigate compliance with TB treatment through feedback reminders, and the scores from wisepill technology predicted successful TB treatment outcomes. This study revealed that HBM constructs such as self-efficacy and perceived barriers (in this case, stigma) significantly predicted overall TB treatment outcomes. These results support the idea that HBM constructs can predict therapeutic adherence in TB patients. According to Gebremariam (2021), self-efficacy increases as the patient successfully resists temptation in high-risk situations (not drinking alcohol, stops taking medication when feeling better). Therefore, TB control management regimens should consider the role of self-efficacy and stigma experienced by TB patients. To attain TB treatment compliance, informational and emotional support will need to be provided to increase self-efficacy and lessen the emotional experience that results from intentional community stigma.

As previously documented by LaMorte (2022), maximising the effective use of the HBM alone is insufficient to achieve behaviour change. It is necessary to integrate the HBM with other models that account for the environmental context to suggest strategies for change. Therefore, the study incorporated the social ecological model to help us understand health behavior as determined by a set of interconnected individual and contextual factors, rather than targeting only one level. Ecological

models assume not only that multiple levels of influence exist but also that these levels are interactive and reinforcing. As with any multifaceted problem, a multipronged approach in this context was able to highlight underlying health outcomes that have long been recommended to guide public health practice (Golden & Earp, 2012). The results indicated that HBM was a suitable model for predicting medication adherence in TB patients. Importantly, when TB patients are confident in their ability to adhere to treatment (self-efficacy), have positive illness cognitions, positive beliefs about the benefits of taking medication, and are not internalising community stigma, they are likely to adhere to treatment. This subsequently results in good clinical outcomes and quality health (Adefolalu, 2018). The TB programme should target interventions that minimise perceived barriers, promote perceived self-efficacy, and alleviate threats to achieve improved adherence to TB treatment.

Furthermore, the benefits of treatment need to be highlighted and encouraged. Self-efficacy in taking medication should be enhanced through programmes motivating TB treatment adherence. In conclusion, Laranjo (2016) also emphasised the importance of using HBM in developing effective behavioural change interventions because it deals with the individual's specific perceptions about susceptibility, benefits, barriers, and self-efficacy. Alongside the HBM, the social ecological model can further support behaviour change interventions by addressing behaviors at multiple social systems that individuals are embedded.

6.3 LIMITATIONS OF THE RESEARCH

This section presents an overview of the limitations of this research.

6.3.1 Wisepill Used as a Proxy for Measuring Medication Adherence

It is important to note that with the patient opening the wisepill box, it was assumed that the medication had been taken, but it did not necessarily imply the ingestion of pills. The analyses assumed that a dose was taken when the opening of the box was registered on the wisepill technology platform; therefore, these registrations were only proxies for medication intake. Messages sent to patients to intervene during the missed intake events were pre-defined and not personalised, nor tailored for the patients. Additional costs were incurred by the researcher to purchase top-ups on airtime provision for SMSs when they were depleted and to enable travel to the health facilities for patient follow-up visits.

6.3.2 Violent Service-delivery Protests Affected Access to the Clinic Facilities

During the data collection phase of this research (enrolment and follow-ups) some residents of Tembisa (Gauteng, South Africa), where the research was conducted, engaged in violent service-delivery protests in July 2022. The protests affected both the study's participants and the researcher as they

prevented access to the clinic for follow-up visits. Thus, alternative arrangements were made in collaboration with the facility-registered nurse to enable seeing the participants at the clinic. The study experienced a challenge with participants of the study relocating to other areas and transferring out of the clinics where the study was taking place. This resulted in discontinuation of the collection of data at subsequent visits. The data were not withdrawn from the study, since "transfer out" (patients for whom the treatment outcome is not known) was handled as an overall TB treatment outcome. This means the unknown TB treatment outcomes of participants who transferred out, whose end of treatment was not found in Tier.Net system were categorised as "transfer out" and treated as an unsuccessful TB treatment outcome.

6.3.3 Electricity Power Outages Affected the Technology's Signal Transmission

The country's (South Africa) electricity power outages during the research period caused interruptions in signal transmission from the cell phone to the technology's server. The synchronisation of the data to the server was delayed. The wisepill devices that the study used were donated and had previously been used. Therefore, the batteries, which are designed to last for six months, kept running low and drained after two to three months. In some cases, this resulted in missing data for measuring adherence. To minimise the missed data, the researcher had to monitor the battery levels constantly and travel to clinics to replace them when necessary. Furthermore, whenever there was a missed signal for more than seven days, the researcher followed up through phone calls and requested the participant to return to the facility to perform troubleshooting for the device so that it could communicate with the server again.

6.3.4 Study Findings Not Generalisable

The sample selected for the study comprised 90 participants who were receiving TB treatment at public clinics in Ekurhuleni, a typical metropolitan area in South Africa. In addition, the sample was not representative of all DS-TB patients in the country; thus, findings could not be generalised. The exclusion of people living with HIV contributed to the low sample size because the majority of potential participants who were approached were co-infected with HIV. The Ekurhuleni district has a high burden of HIV co-infected individuals. The inclusion of HIV-positive patients would have had cost implications for this doctoral study. In addition, the nature of the study is psychological; hence, greater focus was placed on measuring psychological constructs. The small sample size was also due to some potential participants not having access to a cell phone or someone with a cell phone who would to support them by receiving the reminders on their behalf. It is possible that the small number of participants in the study had an impact on the research findings. The power analysis nevertheless

revealed that a sufficient number of participants were included. A large portion of the study sample comprised males, which may have skewed the results.

6.3.5 Bias from Self-reporting Measures

Finally, the subjective nature of self-reporting measures made them vulnerable to questioning the validity of the participants' answers. It is possible that participants may have wanted to please the researcher or to portray themselves in a better light. Self-reporting measures can produce some biased responses (Bauhoff, 2014). In addition, the nature of qualitative research (the data obtained in the qualitative phase of the study) may be subject to different interpretations by different readers.

It is noted that, despite the limitations that were presented, the research findings offer a valuable contribution to the literature regarding the usability of mHealth technology in the context of adherence to TB treatment. Future research could use the current findings as a foundation for improving on the limitations and for exploring scientific evidence on the use of technologies to support medication adherence, specifically in a natural clinic setting.

6.4 RECOMMENDATIONS FOR FURTHER RESEARCH

With a view to mediating the limitations that were noted in the preceding section, the researcher proposes that the following recommendations should be considered for further research:

- ***Enable more follow-up studies for the six months' treatment duration with a larger, more diverse sample size***

A larger sample size would possibly produce increased judgement and findings, particularly on feedback reminders and DS-TB adherence over time. Future research should therefore include a larger, more diverse sample (including cost-effectiveness analysis) to help drive policy decisions concerning the uptake of this technology for routine clinical care. Similar to the research conducted by Guzman et al. (2023), the study recommends that the implementation of adherence technologies should focus on ensuring access, anticipating and resolving technical challenges, and minimising additional cost to people with TB.

- ***To increase conducting trend analysis to understand medication adherence patterns over time***

It is recommended that additional trend analyses on adherence data over time, as collected by wisepill technology, should be conducted to determine whether patterns of adherence could determine which patients required additional treatment support. In addition, trend analyses should explore the

differences between males and females in relation to their interaction with the wisepill technology in support of their medication adherence. Currently, no strong evidence exists indicating that adherence technology interventions improve medication adherence over time among patients with drug-sensitive tuberculosis. Hence, the trend analysis could act as a streamlined approach to identifying patients with adherence issues who require escalated support to manage their adherence and keep them on treatment (over time). Healthcare workers stand to benefit from this approach because they could be enabled to identify patients who need additional adherence support. This could, in turn, contribute to improving patients' TB treatment outcomes. Reserving the use of wisepill technology for patients who need the most support is principally a patient-centred approach that could be integrated into the digital health landscape.

• ***To shorten the standard 6 months treatment duration for drug-susceptible TB (DS-TB) patients***

It is recommended that the current treatment regimen of 6 months for DS-TB be shortned to improve medication adherence. Through the trend analysis, the study was able to demonstrate a decrease in adherence over time and further exarcebated by patient loss to follow-up. Shorter TB regimes are essential in reducing the risk of treatment failure and the development of drug resistance.

• ***To improve design features of the technology***

It is recommended that the wisepill technology should incorporate study participants' insights to maximise their effectiveness and adoption. One of the participants in the study emphasised connecting the pillbox device to a cell phone through Bluetooth, an innovative idea that could be used to replace the existing alarm with music. Through end-user experiences, this study was able to understand the usability of and barriers to using the technology. Furthermore, if the technology could deal with the needs and motivations of end users, the tool will be better adapted to the context-specific environments in which it is operated. Finally, it is important for TB programmes to understand the benefits and limitations that come with using adherence technologies in a clinical care setting to resolve non-adherence to treatment before engaging in the scale-up.

• ***To implement stigma- and self-efficacy-focused prevention and treatment approaches in TB-burdened countries***

It is important to have appropriate psychological support, which will enhance treatment adherence among DS-TB patients who are at risk of interrupting treatment. Based on the findings of the study, it is recommended that interventions be implemented that promote stigma reduction to reduce the probability of early treatment interruption. It is also recommended that further studies should be conducted to understand how TB stigma functions and influences community perceptions.

This information would not only contribute to lessening TB stigmatisation, but would also improve treatment and retention in care. In addition, it is recommended that targeted interventions should be implemented that are aimed at identifying patients with low levels of self-efficacy in clinical settings. This is a form of support that could help these patients to develop the necessary confidence to manage their treatment, which includes taking their medicine irrespective of any challenges they might be faced with (also relieving the associated stigma). The TB programme, health professionals and policymakers are urged to consider the recommendations of the study in respect of overcoming self-stigma and increasing self-efficacy to promote medication adherence among patients with TB disease.

6.5 SIGNIFICANCE OF THIS RESEARCH

This study produced convincing evidence that an adherence technology holds promise for improving patient-centred TB adherence monitoring. Although, over time wisepill technology did not increase medication over time, the trend pattern was able to pin-point problematic stages in TB treatment – this critical understanding can inform the development of focused interventions to improve adherence. Furthermore, the issue with patient loss to follow-up can be addressed by introducing shorter TB regimes. This could have a positive impact on the quality of life for TB patients and in future make it easier to treat TB. In a resource-limited setting like South Africa, wisepill technology was able to predict favourable treatment outcomes among DS-TB patients. The study highligheted discrepancies between wisepill technology scores and other subjective measures of adherence when used in clinical practice. This further builds on the current evidence that subjective measures of adherence remain subject to personal bias. Participants of the study found the wisepill box usable for supporting their medication adherence. An overall understanding of experiences with using the wisepill adherence tool to support medication adherence was derived from the end users of the technology. In addition, end users identified programme-specific issues related to the use of the technology over the short- and long term (barriers to adoption and sustainable use of the wisepill technology). Furthermore, in this context, the psychological constructs stigma and self-efficacy played a significant role in predicting adherence behaviour. Therefore, screening for stigma and self-efficacy at health facilities upon initation is key for identifying and profiling earlier the TB patients support needs that can help them to adhere and complete treatment. This study generated predominantly critical evidence-based knowledge on mHealth use and adherence over time, specifically within the South African context. Using mobile technology to understand medication adherence in TB disease treatment is an important contribution to the TB programmes, because it reflects the patients' role in exercising personal agency to improve their health outcome.

Therefore, it is important to invest in TB intervention programmes that seek to improve medication adherence among DS-TB patients because this effort will contribute to reducing the number of unsuccessful TB treatment outcomes and lower TB treatment resistance.

In conclusion, the study's findings highlighted the need for more large-scale research to be conducted in a clinical setting to implement adherence technologies and psychological strategies for sustained optimal TB treatment.

REFERENCES

Abdisa, E., Fekadu, G., Girma, S., Shibiru, T., Tilahun, T., Mohamed, H., Wakgari, A., Takele, A., Abebe, M., & Tsegaye, R. (2020). Self-stigma and medication adherence among patients with mental illness treated at Jimma University Medical Center, Southwest Ethiopia. *International Journal of Mental Health Systems*, *14*, 1–13. https://ijmhs.biomedcentral.com/articles/10.1186/s13033-020-00391-6

Acosta, J., Flores, P., Alarcón, M., Grande-Ortiz, M., Moreno-Exebio, L., & Puyen, Z. M. (2022). A randomised controlled trial to evaluate a medication monitoring system for TB treatment. *The International Journal of Tuberculosis and Lung Disease*, *26*(1), 44–49. doi: 10.5588/ijtld.21.0373

Adams, R. J. (2010). Improving health outcomes with better patient understanding and education. *Risk Management and Healthcare Policy*, *3*, 61. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3270921/

Adane, A. A., Alene, K. A., Koye, D. N., & Zeleke, B. M. (2013). Non-adherence to anti-tuberculosis treatment and determinant factors among patients with tuberculosis in northwest Ethiopia. *PloS One, 8*(11), e78791. https://doi.org/10.1371/journal.pone.0078791

Adefolalu, A. O. (2018). Cognitive-behavioural theories and adherence: Application and relevance in antiretroviral therapy. *Southern African Journal of HIV Medicine, 19*(1), 1–7. doi: 10.4102/sajhivmed.v19i1.762

Adefolalu, A., Nkosi, Z., Olorunju, S., & Masemola, P. (2014). Self-efficacy, medication beliefs and adherence to antiretroviral therapy by patients attending a health facility in Pretoria. *South African Family Practice*, *56*(5), 281–285. https://www.tandfonline.com/doi/full/10.1080/20786190.2014.975476

Adisa, R., Ayandokun, T. T., & Ige, O. M. (2021). Knowledge about tuberculosis, treatment adherence and outcome among ambulatory patients with drug-sensitive tuberculosis in two directly-observed treatment centres in Southwest Nigeria. *BMC Public Health*, *21*(1), 677. https://doi.org/10.1186/s12889-021-10698-9

Agarwal, S., Crespo-Ramos, G., Long, J. A., & Miller, V. A. (2021). "I didn't really have a choice": qualitative analysis of racial-ethnic disparities in diabetes technology use among young adults with type 1 diabetes. *Diabetes Technology & Therapeutics*, *23*(9), 616–622. doi:10.1089/dia.2021.0075

Ahmad A, Rasul T, Yousaf A, Zaman U. (2020). Understanding factors influencing elderly diabetic patients' continuance intention to use digital health wearables: Extending the technology

acceptance model (TAM*). Journal of Open Innovation: Technology, Market, and Complexity, 6*(3):81. https://doi.org/10.3390/joitmc6030081

Ahmedani, B. K. (2011). Mental health stigma: Society, individuals, and the profession. *Journal of Social Work Values and Ethics, 8*(2), 4-1–4-16. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3248273/

Aibana, O., Dauria, E., Kiriazova, T., Makarenko, O., Bachmaha, M., Rybak, N., Flanigan, T. P., Petrenko, V., Becker, A. E., & Murray, M. B. (2020). Patients' perspectives of tuberculosis treatment challenges and barriers to treatment adherence in Ukraine: A qualitative study. *BMJ Open, 10*(1), e032027. https://doi.org/10.1136/bmjopen-2019-032027

Aikenhead, G. (1997, May). A framework for reflecting on assessment and evaluation. In *Globalization of Science Education: International Conference on Science Education.,* Seoul, Korea. May (pp. 26–30).

Akbar, N., Nursasi, A. Y., & Wiarsih, W. (2020). Does self-stigma affect self-efficacy on treatment compliance of tuberculosis clients? *Indonesian Contemporary Nursing Journal (ICON Journal),* 36–41. https://journal.unhas.ac.id/index.php/icon/article/view/9645

Al Hashmi, I., & Al Omari, O. (2022). Self-efficacy in relation to adherence to healthy behaviours among pregnant women: a concept analysis. *Central European Journal of Nursing and Midwifery, 13*(2), 664. https://cejnm.osu.cz/artkey/cjn-202202-0001_self-efficacy-in-relation-to-adherence-to-healthy-behaviours-among-pregnant-women-a-concept-analysis.php

Aldeer, M., Javanmard, M., & Martin, R. (2018). A review of medication adherence monitoring technologies. *Applied System Innovation, 1*(2), 14. https://doi.org/10.3390/asi1020014

Alharahsheh, H. H., & Pius, A. (2020). A review of key paradigms: Positivism vs interpretivism. *Global Academic Journal of Humanities and Social Sciences, 2*(3), 39–43. doi: 10.36348/gajhss.2020.v02i03.001

Alhazami, M., Pontinha, V. M., Patterson, J. A., & Holdford, D. A. (2020). Medication adherence trajectories: A systematic literature review. *Journal of Managed Care & Specialty Pharmacy, 26*(9), 1138–1152. https://www.jmcp.org/doi/full/10.18553/jmcp.2020.26.9.1138

Ali, E. E., Chan, S. S. L., Leow, J. L., Chew, L., & Yap, K. Y. L. (2019). User acceptance of an app-based adherence intervention: perspectives from patients taking oral anticancer medications. *Journal of Oncology Pharmacy Practice, 25*(2), 390–397. doi: 10.1177/1078155218778106

Alipanah, N., Jarlsberg, L., Miller, C., Linh, N. N., Falzon, D., Jaramillo, E., & Nahid, P. (2018). Adherence interventions and outcomes of tuberculosis treatment: A systematic review and meta-analysis of trials and observational studies. *PLoS Medicine, 15*(7). https://doi.org/10.1371/journal.pmed.1002595

Allana, S., & Clark, A. (2018). Applying meta-theory to qualitative and mixed-methods research: A discussion of critical realism and heart failure disease management interventions research. *International Journal of Qualitative Methods*, *17*(1), 1609406918790042. https://doi.org/10.1177/1609406918790042

Allemang, B., Sitter, K., & Dimitropoulos, G. (2022). Pragmatism as a paradigm for patient-oriented research. *Health Expectations*, *25*(1), 38–47. https://doi.org/10.1111/hex.13384

Alobu, I., Oshi, S. N., Oshi, D. C., & Ukwaja, K. N. (2014). Risk factors of treatment default and death among tuberculosis patients in a resource-limited setting. *Asian Pacific Jjournal of Tropical Medicine, 7*(12), 977–984. https://doi.org/10.1016/S1995-7645(14)60172-3

Amer, F. A., Mohamed, M. S., Elbur, A. I., Abdelaziz, S. I., & Elrayah, Z. A. (2018). Influence of self-efficacy management on adherence to self-care activities and treatment outcome among diabetes mellitus type 2. *Pharmacy Practice (Granada)*, *16*(4). https://scielo.isciii.es/scielo.php?pid=S1885-642X2018000400003&script=sci_arttext

Ames, H. M., Glenton, C., Lewin, S., Tamrat, T., Akama, E., Leon, N., & Cochrane Consumers and Communication Group. (1996). Clients' perceptions and experiences of targeted digital communication accessible via mobile devices for reproductive, maternal, newborn, child, and adolescent health: a qualitative evidence synthesis. *Cochrane Database of Systematic Reviews*, *2019*(10). doi: 10.1002/14651858.CD013447

Amuha, M. G., Kutyabami, P., Kitutu, F. E., Odoi-Adome, R., & Kalyango, J. N. (2009). Non-adherence to anti-TB drugs among TB/HIV co-infected patients in Mbarara Hospital Uganda: prevalence and associated factors. *African Health Sciences, 9* (Suppl 1), S8–S15. https://pubmed.ncbi.nlm.nih.gov/20589161/

Andersen, L.S., Magidson, J.F., O'Cleirigh, C., Remmert, J.E., Kagee, A., Leaver, M., Stein, D.J., Safren, S.A., & Joska, J. (2018). A pilot study of a nurse-delivered cognitive behavioral therapy intervention (Ziphamandla) for adherence and depression in HIV in South Africa. *Journal of Health Psychology*, *23*(6), 776–787. doi: 10.1177/1359105316643375.

Anderson, E., Cochrane, A., Golding, J., & Nowicki, S. (2018). Locus of control as a modifiable risk factor for cognitive function in midlife. *Aging, 10*(7), 1542–1555. https://doi.org/10.18632/aging.101490

Andrade, S. E., Kahler, K. H., Frech, F., & Chan, K. A. (2006). Methods for evaluation of medication adherence and persistence using automated databases. *Pharmacoepidemiology and Drug Safety, 15*(8), 565–577. https://doi.org/10.1002/pds.1230

Anghel, L. A., Farcas, A. M., & Oprean, R. N. (2019). An overview of the common methods used to measure treatment adherence. *Medicine and Pharmacy Reports, 92*(2), 117. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6510353/

Antwi, S. K., & Hamza, K. (2015). Qualitative and quantitative research paradigms in business research: A philosophical reflection. *European Journal of Business and Management, 7*(3), 217-225. https://www.scirp.org/reference/referencespapers?referenceid=2505953

Aregbesola, O. H., & Adeoye, I. A. (2018). Self-efficacy and antiretroviral therapy adherence among HIV positive pregnant women in South-West Nigeria: A mixed methods study. *Tanzania Journal of Health Research, 20*(4). doi:10.4314/thrb.v20i4.x

Arindari, D. R., & Suswitha, D. (2020). Health belief model factors to medication adherence among hypertensive patients in Punti Kayu Public Health Center Palembang, Indonesia. *Jurnal Keperawatan. 11*(1). https://doi.org/10.22219/jk.v11i1.10483.

Arnsten, J.H., Demas, P.A., Farzadegan, H., Grant, R.W., Gourevitch, M.N., Chang, C.J., Buono, D., Eckholdt, H., Howard, A.A., & Schoenbaum, E.E. (2001). Antiretroviral therapy adherence and viral suppression in HIV-infected drug users: comparison of self-report and electronic monitoring. *Clinical Infectious Diseases, 33*(8), 1417–1423. https://academic.oup.com/cid/article/33/8/1417/348209

Arshed, M., Mahmud, A. B., Minhat, H. S., Ying, L. P., & Umer, M. F. (2023). Effectiveness of mHealth Interventions in Medication Adherence among Patients with Cardiovascular Diseases: A Systematic Review. *Diseases (Basel, Switzerland), 11*(1), 41. https://doi.org/10.3390/diseases11010041

A spotlight on the tuberculosis epidemic in South Africa. (2024) *Nature Communications, 15*, 1290 (2024). https://doi.org/10.1038/s41467-024-45491-w

Assefa, D. G., Dememew, Z. G., Zeleke, E. D., Manyazewal, T., & Bedru, A. (2024). Financial burden of tuberculosis diagnosis and treatment for patients in Ethiopia: A systematic review and meta-analysis. *BMC Public Health, 24*(1), 260. https://doi.org/10.1186/s12889-024-17713-9

Astin, F., & Jones, K. (2006). Changes in patients' illness representations before and after elective percutaneous transluminal coronary angioplasty. *Heart & Lung: The Journal of Critical Care, 35*(5), 293–300. https://doi.org/10.1016/j.hrtlng.2005.09.006

Astley, W. G. (2019). Administrative science as socially constructed truth. *Postmodern management theory* (pp. 3–19). Routledge.

Ayana, T. M., Roba, K. T., & Mabalhin, M. O. (2019). Prevalence of psychological distress and associated factors among adult tuberculosis patients attending public health institutions in Dire Dawa and Harar cities, Eastern Ethiopia. *BMC Public Health, 19*, 1-–9. https://doi.org/10.1186/s12889-019-7684-2

Azizi, N., Karimy, M., & Salahshour, V. N. (2018). Determinants of adherence to tuberculosis treatment in Iranian patients: Application of health belief model. *The Journal of Infection in Developing Countries*, *12*(09), 706–711. https://jidc.org/index.php/journal/article/view/31999627

Babalola, E., Noel, P., & White, R. (2017). The biopsychosocial approach and global mental health: Synergies and opportunities. *Indian Journal of Social Psychiatry*, 33(4), 291–296. doi: 10.4103/ijsp.ijsp_13_17

Bachman Desilva, M., Gifford, A. L., Keyi, X., Li, Z., Feng, C., Brooks, M., Harrold, M., Yueying, H., Gill, C. J., Wubin, X., Vian, T., Haberer, J., Bangsberg, D., & Sabin, L. (2013). Feasibility and acceptability of a real-time adherence device among HIV-positive IDU patients in China. *AIDS Research and Treatment*, 2013, 957862. https://doi.org/10.1155/2013/957862

Backes, C., Moyano, C., Rimaud, C., Bienvenu, C., & Schneider, M. P. (2021). Digital medication adherence support: could healthcare providers recommend mobile health apps? *Frontiers in Medical Technology, 2,* 616242. https://doi.org/10.3389/fmedt.2020.616242

Badawy, R., Hameed, F., Bataille, L., Little, M. A., Claes, K., Saria, S., Cedarbaum, J. M., Stephenson, D., Neville, J., Maetzler, W., Espay, A. J., Bloem, B. R., Simuni, T., & Karlin, D. R. (2019). Metadata concepts for advancing the use of digital health technologies in clinical research. *Digital Biomarkers, 3*(3), 116–132. https://doi.org/10.1159/000502951

Baloyi, N. F., & Manyisa, Z. M. (2022). Patients' perceptions on the factors contributing to non-conversion after two months of tuberculosis treatment at selected primary healthcare facilities in the Ekurhuleni health district, South Africa. *The Open Public Health Journal*, *15*(1). https://doi.org/10.2174/18749445-v15-e2208291

Bandura, A. (1986). *Social foundations of thought and action.* Prentice Hall 1986(23–28), 2.

Bandura, A. (1988). Organizational applications of social cognitive theory. *Australian Journal of Management Manage*. *13*(2), 275–302. https://doi.org/10.1177/031289628801300210

Bandura, A. (1989). Human agency in social cognitive theory. *American Psychologist*, *44*(9), 1175. Retrieved from https://doi.org/10.1037/0003-066X.44.9.1175

Bandura, A. (2001). Social cognitive theory: An agentic perspective. *Annual Review of Psychology*, *52*(1), 1–26. https://psycnet.apa.org/record/2001-00511-001

Bandura, A. (2004). Health promotion by social cognitive means. *Health Education & Behavior Journal, 31*(2), 143–164. https://doi.org/10.1177/1090198104263660

Bandura, A., & Adams, N. E. (1997). Analysis of self-efficacy theory of behavioural change. *Cognitive Therapy and Research, 1*(4), 287–310. https://doi.org/10.1007/BF01663995

Bandura, A., & Walters, R. H. (1977). *Social learning theory* (Vol. 1, pp. 141–154). Prentice Hall.

Bangsberg, D. R., & Deeks, S. G. (2010). Spending more to save more: interventions to promote adherence. *Annals of Internal Medicine, 152*(1), 54–13. https://doi.org/10.7326/0003-4819-152-1-201001050-00012

Bao, Y., Wang, C., Xu, H., Lai, Y., Yan, Y., Ma, Y., Yu, T., & Wu, Y. (2022). Effects of an mHealth intervention for pulmonary tuberculosis self-management based on the integrated theory of health behavior change: randomized controlled trial. *JMIR Public Health and Surveillance, 8*(7), e34277. doi: 10.2196/34277

Bardosh, K. L., Murray, M., Khaemba, A. M., Smillie, K., & Lester, R. (2017). Operationalizing mHealth to improve patient care: a qualitative implementation science evaluation of the WelTel texting intervention in Canada and Kenya. *Globalization and Health*, *13*, 1–15. https://globalizationandhealth.biomedcentral.com/articles/10.1186/s12992-017-0311-z

Bauhoff, S. (2014). Self-report bias in estimating cross-sectional and treatment effects. *Encyclopedia of quality of life and well-being research*, 5798–5800. https://link.springer.com/referenceworkentry/10.1007/978-94-007-0753-5_4046

Becker, M. H. (1974). The health belief model and personal health behavior. *Health Education Monographs, 2,* 324–473. https://cir.nii.ac.jp/crid/1571698600460560768

Becker, S., Bryman, A., & Ferguson, H. (2012*). Understanding research for social*

behavioural research. Sage.

Benyamini, Y., Gozlan, M., & Kokia, E. (2004). On the self-regulation of a health threat: Cognitions, coping, and emotions among women undergoing treatment for infertility. Cognitive Therapy and Research, 28(5), 577–592. https://doi.org/10.1023/B:COTR.0000045566.97966.22

Bernard, H.R. (2002). *Research methods in anthropology: Qualitative and quantitative methods*. AltaMira Press.

Berry, J. D., Paganoni, S., Carlson, K., Burke, K., Weber, H., Staples, P., Salinas, J., Chan, J., Green, J. R., Connaghan, K., Barback, J., & Onnela, J. P. (2019). Design and results of a smartphone-based digital phenotyping study to quantify ALS progression. *Annals of Clinical and Translational Neurology, 6*(5), 873–881. https://doi.org/10.1002/acn3.770

Berry, K. M., Rodriguez, C. A., Berhanu, R. H., Ismail, N., Mvusi, L., Long, L., & Evans, D. (2019). Treatment outcomes among children, adolescents, and adults on treatment for tuberculosis in two metropolitan municipalities in Gauteng Province, South Africa. *BMC Public Health, 19*(1), 973. https://doi.org/10.1186/s12889-019-7257-4

Berry, N., Lobban, F., & Bucci, S. (2019). A qualitative exploration of service user views about using digital health interventions for self-management in severe mental health problems. *BMC Psychiatry*, *19*(1), 1–13. https://bmcpsychiatry.biomedcentral.com/articles/10.1186/s12888-018-1979-1

Biesta, G. (2021). *Pragmatism and the philosophical foundations of mixed methods research*. Sage.

Bionghi, N., Daftary, A., Maharaj, B., Msibi, Z., Amico, K. R., Friedland, G., Orrell, C., Padayatchi, N., & O'Donnell, M. R. (2018). Pilot evaluation of a second-generation electronic pill box for adherence to Bedaquiline and antiretroviral therapy in drug-resistant TB/HIV co-infected patients in KwaZulu-Natal, South Africa. *BMC Infectious Diseases*, *18*(1), 171. doi:10.1186/s12879-018-3080-2

Blackwell, B. (1992). Compliance. *Psychotherapy and Psychosomatics*, *58*(3–4), 161–169. https://doi.org/10.1159/000288624

Blake Helms, C., Turan, J. M., Atkins, G., Kempf, M. C., Clay, O. J., Raper, J. L., Mugavero, M. J., & Turan, B. (2017). Interpersonal mechanisms contributing to the association between HIV-related internalized stigma and medication adherence. *AIDS and Behavior, 21*(1), 238–247. https://doi.org/10.1007/s10461-016-1320-2

Bloomberg, L. D., & Volpe, M. (2018). *Completing your qualitative dissertation: A road map from beginning to end*. Sage.

Bloomberg, L.D., & Volpe, M. (2019). *Completing your qualitative dissertation: A road map from beginning to end*. Sage.

Boateng, G. O., Neilands, T. B., Frongillo, E. A., Melgar-Quiñonez, H. R., & Young, S. L. (2018). Best practices for developing and validating scales for health, social, and behavioral research: a primer. *Frontiers in Public Health, 6*, 149. doi: 10.3389/fpubh.2018.00149

Borrell-Carrió, F., Suchman, A. L., & Epstein, R. M. (2004). The biopsychosocial model 25 years later: Principles, practice, and scientific inquiry. *The Annals of Family Medicine, 2*(6), 576–582. https://www.annfammed.org/content/2/6/576?fbclid=IwAR0_RoNjdXAmAyReX0RY26oHNQ5FaoNN-mUR09niV3lQD-nrEcb-tx92xcQ

Bosworth, H. B., Blalock, D. V., Hoyle, R. H., Czajkowski, S. M., & Voils, C. I. (2018). The role of psychological science in efforts to improve cardiovascular medication adherence. *American Psychologist, 73*(8), 968. https://psycnet.apa.org/record/2018-54176-003

Boukhechba, M., Baee, S., Nobles, A. L., Gong, J., Wells, K., & Barnes, L. E. (2018, March). A social cognitive theory-based framework for monitoring medication adherence applied to endocrine therapy in breast cancer survivors. In *2018 IEEE EMBS International Conference on Biomedical & Health Informatics (BHI)* (pp. 275–278). IEEE. doi: 10.1109/BHI.2018.8333422

Broomhead, S., & Mars, M. (2012). Retrospective return on investment analysis of an electronic treatment adherence device piloted in the Northern Cape Province. *Telemedicine and e-Health, 18*(1), 24–31. https://doi.org/10.1089/tmj.2011.0143

Bucci, S., Schwannauer, M., & Berry, N. (2019). The digital revolution and its impact on mental health care. *Psychology and Psychotherapy: Theory, Research and Practice*, 92(2), 277–297. https://doi.org/10.1111/papt.12222

Burrell, W. G., & Morgan, G. (2017). *Sociological paradigms and organizational analysis*. Routledge.

Burrell, G., & Morgan, G. (2019). *Sociological paradigms and organisational analysis: Elements of the sociology of corporate life*. Routledge.

Burtscher, D., van den Bergh, R., Toktosunov, U., Angmo, N., Samieva, N., & Rocillo Arechaga, E. P. (2016). "My Favourite Day Is Sunday": Community perceptions of (drug-resistant) tuberculosis and ambulatory tuberculosis care in Kara Suu District, Osh Province, Kyrgyzstan. *PloS One, 11*(3), e0152283. https://doi.org/10.1371/journal.pone.0152283

Carmody, P. (2019). *Development theory and practice in a changing world*. Routledge.

Carson, D., Gilmore, A., Perry, C., & Gronhaug, K. (2001). *Qualitative marketing research*. Sage.

Castillo-Mancilla, J. R., & Haberer, J. E. (2018). Adherence measurements in HIV: new advancements in pharmacologic methods and real-time monitoring. *Current HIV/Aids Reports, 15*, 49–59. https://link.springer.com/article/10.1007/s11904-018-0377-0

Cecere, L. M., Slatore, C. G., Uman, J. E., Evans, L. E., Udris, E. M., Bryson, C. L., & Au, D. H. (2012). Adherence to long-acting inhaled therapies among patients with chronic obstructive pulmonary disease (COPD). *COPD: Journal of Chronic Obstructive Pulmonary Disease, 9*(3), 251–258. https://www.tandfonline.com/doi/full/10.3109/15412555.2011.650241

Cele, M. A., & Archary, M. (2019). Acceptability of short text messages to support treatment adherence among adolescents living with HIV in a rural and urban clinic in KwaZulu-Natal. *Southern African Journal of HIV Medicine, 20*(1), 976. https://doi.org/10.4102/sajhivmed.v20i1.976

Champion, K. E., Parmenter, B., McGowan, C., Spring, B., Wafford, Q. E., Gardner, L. A., Thornton, L., McBride, N., Barrett, E.L., Teesson, M., & Mewton, L. (2019). Effectiveness of school-based eHealth interventions to prevent multiple lifestyle risk behaviours among adolescents: a systematic review and meta-analysis. *The Lancet Digital Health, 1*(5), e206-e221. https://www.thelancet.com/journals/landig/article/PIIS2589-7500(19)30088-3/fulltext

Chandru, B. A., & Varma, R. P. (2023). Factors affecting ability of TB patients to follow treatment guidelines - applying a capability approach. *International Journal for Equity in Health, 22*(1), 176. https://doi.org/10.1186/s12939-023-01991-7

Chang, S. H., & Cataldo, J. K. (2014). A systematic review of global cultural variations in knowledge, attitudes and health responses to tuberculosis stigma. *The International Journal of Tuberculosis and Lung Disease,18*(2), 168–173. https://doi.org/10.5588/ijtld.13.0181

Chauke, G. D., Nakwafila, O., Chibi, B., Sartorius, B., & Mashamba-Thompson, T. (2022). Factors influencing poor medication adherence amongst patients with chronic disease in low-and-middle-income countries: A systematic scoping review. *Heliyon, 8(*6). https://www.sciencedirect.com/science/article/pii/S2405844022010040

Checchi, K. D., Huybrechts, K. F., Avorn, J., & Kesselheim, A. S. (2014). Electronic medication packaging devices and medication adherence: a systematic review. *Jama, 312*(12), 1237–1247. doi:10.1001/jama.2014.10059

Cheen, M. H. H., Tan, Y. Z., Oh, L. F., Wee, H. L., & Thumboo, J. (2019). Prevalence of and factors associated with primary medication non-adherence in chronic disease: A systematic review and meta-analysis. *International Journal of Clinical Practice, 73*(6), e13350. https://doi.org/10.1111/ijcp.13350

Chen, X., Xu, J., Chen, Y., Wu, R., Ji, H., Pan, Y., Duan, Y., Sun, M., Du, L., Gao, M., Wang, J., & Zhou, L. (2021). The relationship among social support, experienced stigma, psychological

distress, and quality of life among tuberculosis patients in China. *Scientific Reports, 11*(1), 24236. doi: 10.1038/s41598-021-03811-w

Cheng, C-M., Chang, C-C., Wang, J-D., Chang, K-C., Ting, S-Y., & Lin, C-Y. (2019). Negative impacts of self-stigma on the quality of life of patients in methadone maintenance treatment: The mediated roles of psychological distress and social functioning. *International Journal of Environmental Research and Public Health, 16*(7),1299. https://doi.org/10.3390/ijerph16071299

Chiang, I. C. A., Jhangiani, R. S., & Price, P. C. (2015). Reliability and validity of measurement. *Research methods in psychology-2nd Canadian Ed.*

Chilisa, B., & Kawulich, B. (2012). Selecting a research approach: paradigm, methodology and methods. University of Georgia. https://www.researchgate.net/publication/257944787

Chirwa, T., Nyasulu, P., Chirwa, E., Ketlogetswe, A., Bello, G., Dambe, I., Ndalama, D., & Joshua, M. (2013). Levels of tuberculosis treatment adherence among sputum smear positive pulmonary tuberculosis patients attending care at Zomba Central hospital, southern Malawi, 2007-2008. *PloS One, 8*(5), e63050. https://doi.org/10.1371/journal.pone.0063050

Chun-Yun Kang, G. (2022). Technology-based interventions to improve adherence to antihypertensive medications–An evidence-based review. *Digital Health*, *8*, 20552076221089725. https://journals.sagepub.com/doi/10.1177/20552076221089725

Clark, A. M. (1998). The qualitative-quantitative debate: Moving from positivism and confrontation to post-positivism and reconciliation. *Journal of Advanced Nursing, 27*(6), 1242–1249. https://doi.org/10.1046/j.1365-2648.1998.00651.x

Clark, N. M., & Dodge, J. A. (1999). Exploring self-efficacy as a predictor of disease management. *Health Education and Behaviour, 26*(1), 72–89. https://doi.org/10.1177/109019819902600107

Clarke, V., & Braun, V. (2013). *Successful qualitative research: A practical guide for beginners.* Sage

Cohen, J. (1988). *Statistical power analyses for the social sciences*. Lawrence Erlbaum Associates.

Collaco, J. M., Kole, A. J., Riekert, K. A., Eakin, M. N., Okelo, S. O., & McGrath-Morrow, S. A. (2012). Respiratory medication adherence in chronic lung disease of prematurity. *Pediatric Pulmonology, 47*(3), 283–291. doi: 10.1002/ppul.21547

Comte, A., & Martineau, H. (1974). *The positive philosophy*. Cambridge University Press

Cook, T. D., & D. T. Campbell (1979). *Quasi-experimentation: Design and analysis issues for field settings*. Rand McNally

Copelyn, J. (2023). *In-depth: What government is doing to reduce medicines stockouts.* Spotlight. https://www.spotlightnsp.co.za/2023/10/31/in-depth-what-government-is-doing-to-reduce-medicines-stockouts/

Corrigan, P. (2004). How stigma interferes with mental health care. *American Psychologist, 59*(7), 614.

Corrigan, P. W., & Kleinlein, P. (2005). The impact of mental illness stigma. In P. W. Corrigan (Ed.), *On the stigma of mental illness: Practical strategies for research and social change* (pp. 11–44). American Psychological Association. https://doi.org/10.1037/10887-001

Corrigan, P. W., Larson, J. E., & Kuwabara, S. A. (2010). Social psychology of the stigma of mental illness: Public and self-stigma models. In J. E. Maddux & J. P. Tangney (Eds.), Social psychological foundations of clinical psychology (pp. 51–68). Guilford Press.

Corrigan, P. W., Watson, A. C., & Barr, L. (2006). The self–stigma of mental illness: Implications for self–esteem and self–efficacy. *Journal of Social and Clinical Psychology, 25*(8), 875–884. doi:10.1521/jscp.2006.25.8.875

Cortina, J. M. (1993). What is coefficient alpha? An examination of theory and applications. *Journal of Applied Psychology*, *78*(1), 98. https://doi.org/10.1037/0021-9010.78.1.98

Courtwright, A., & Turner, A. N. (2010). Tuberculosis and stigmatization: Pathways and interventions. *Public Health Reports*, *125*(4_suppl), 34-42. doi: 10.1177/00333549101250S407

Craig, G. M., Daftary, A., Engel, N., O'Driscoll, S., & Ioannaki, A. (2017). Tuberculosis stigma as a social determinant of health: a systematic mapping review of research in low incidence countries. *International Journal of Infectious Diseases*, *56*, 90–100. https://www.sciencedirect.com/science/article/pii/S120197121631195X

Cremers, A. L., de Laat, M. M., Kapata, N., Gerrets, R., Klipstein-Grobusch, K., & Grobusch, M. P. (2015). Assessing the consequences of stigma for tuberculosis patients in urban Zambia. *PloS One, 10*(3), e0119861. https://doi.org/10.1371/journal.pone.0119861

Creswell, J. W. (2015). *A concise introduction to mixed methods research*. Sage.

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage.

Creswell, J.W. (2003). *Research design: Qualitative, quantitative and mixed methods approaches*. Sage.

Creswell, J.W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage.

Creswell, J.W., & Plano-Clark, V.L. (2011). *Designing and conducting mixed-methods research*. Sage.

Creswell, J.W., & Plano-Clark, V.L. (2017). *Designing and conducting mixed- methods research*. Sage.

Crocker, J., Major, B., & Steele, C., (1998). Social stigma. In Gilbert, D. T., Fiske, S. T., & Lindzey, G. (eds.) *The handbook of social psychology,* (4th ed. pp.504-–553). Academic Press.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16*(3), 297–334. https://doi.org/10.1007/BF02310555

Cross, A., Gupta, N., Liu, B., Nair, V., Kumar, A., Kuttan, R., Ivatury, P., Chen, A., Lakshman, K., Rodrigues, R., D'Souza, G., Chittamuru, D., Rao, R., Rade, K., Vadera, B., Shah, D., Choudary, V., Chada, V., Shah, A., …Thies, W. (2019, January). 99DOTS: a low-cost approach to monitoring and improving medication adherence. In *Proceedings of the Tenth International Conference on Information and Communication Technologies and Development* (pp. 1-12). https://dl.acm.org/doi/abs/10.1145/3287098.3287102

Das, R., Baidya, S., Das, J. C., & Kumar, S. (2015). A study of adherence to DOTS regimen among pulmonary tuberculosis patients in West Tripura District. *The Indian Journal of Tuberculosis, 62*(2), 74–79. https://doi.org/10.1016/j.ijtb.2015.04.005

Davis, D. W. (2004). Validity and reliability: Part I. *Neonatal Network: NN, 23*(1), 54–56. https://doi.org/10.1891/0730-0832.23.1.54

de Almeida Crispim, J., da Silva, L. M. C., Yamamura, M., Popolin, M. P., Ramos, A. C. V., Arroyo, L. H., de Queiroz, A.A.R., de Souza Belchior, A., Dos Santos, D.T., Pieri, F.M., Rodrigues, L.B.B, Protti, S.D., Pinto, I.C., Palha, P.F., & Arcêncio, R. A. (2017). Validity and reliability of the tuberculosis-related stigma scale version for Brazilian Portuguese. *BMC Infectious Diseases*, *17*, 1–8. https://bmcinfectdis.biomedcentral.com/articles/10.1186/s12879-017-2615-2

de Bruin, M., Oberjé, E. J., Viechtbauer, W., Nobel, H.-E., Hiligsmann, M., van Nieuwkoop, C., Veenstra, J., Pijnappel, F.J., Kroon, F.P., van Zonneveld, L., & Groeneveld, P.H. (2017). Effectiveness and cost-effectiveness of a nurse-delivered intervention to improve adherence

to treatment for HIV: a pragmatic, multicentre, open-label, randomised clinical trial. *The Lancet Infectious Diseases, 17*(6), 595–604. https://doi.org/10.1016/S1473-3099(16)30534-5

de Groot, L. M., Straetemans, M., Maraba, N., Jennings, L., Gler, M. T., Marcelo, D., Mekoro, M., Steenkamp, P., Gavioli, R., Spaulding, A., Prophete, E., Bury, M., Banu, S., Sultana, S., Onjare, B., Efo, E., Alacapa, J., Levy, J., Morales, M.L.M.,… Cattamanchi, A. (2022). Time trend analysis of tuberculosis treatment while using digital adherence technologies—An individual patient data meta-analysis of eleven projects across ten high tuberculosis-burden countries. *Tropical Medicine and Infectious Disease, 7*(5), 65. https://doi.org/10.3390/tropicalmed7050065

de Hert, M., Cohen, D., Bobes, J., Cetkovich-Bakmas, M., Leucht, S., Ndetei, D. M., Newcomer, J. W., Uwakwe, R., Asai, I., Möller, H. J., Gautam, S., Detraux, J., & Correll, C. U. (2011). Physical illness in patients with severe mental disorders. II. Barriers to care, monitoring and treatment guidelines, plus recommendations at the system and individual level. *World Psychiatry, 10*(2), 138–151. https://doi.org/10.1002/j.2051-5545.2011.tb00036.x

de Villiers, K. (2021). Bridging the health inequality gap: an examination of South Africa's social innovation in health landscape. *Infectious Diseases of Poverty, 10*, 1–7. https://idpjournal.biomedcentral.com/articles/10.1186/s40249-021-00804-9

Deetz, S. (1996). Describing differences in approaches to organization science: Rethinking Burrell and Morgan and their legacy. *Organization Science, 7*(2), 191–207. doi:10.1287/orsc.7.2.191

DeLuca, D., Gallivan, M J., & Kock, N. (2008). Furthering information systems action research: A post-positivist synthesis of four dialectics. *Business Faculty Publications*. 140. https://rio.tamiu.edu/arssb_facpubs/140

Demonceau, J., Ruppar, T., Kristanto, P., Hughes, D. A., Fargher, E., Kardas, P., de Geest, S., Dobbels, F., Lewek, P., Urquhart, J., Vrijens, B. (2013). Identification and assessment of adherence-enhancing interventions in studies assessing medication adherence through electronically compiled drug dosing histories: A systematic literature review and meta-analysis. *Drugs, 73*(6), 545–562. https://link.springer.com/article/10.1007/s40265-013-0041-3

Denkinger, C., Grenier, J., Stratis, A., Akkihal, A., Pant-Pai, N., & Pai, M. (2013). Mobile health to improve tuberculosis care and control: a call worth making. *The International Journal of Tuberculosis and Lung Disease, 17*(6), 719–727. doi: 10.5588/ijtld.12.0638

Denzin, N.K., & Lincoln, Y.S. (2011). *The SAGE handbook of qualitative research*. Sage.

Department of Health. (2014). *National Tuberculosis Management Guidelines*. Pretoria: Department of Health. https://knowledgehub.health.gov.za/elibrary/national-tuberculosis-management-guidelines

DeSanto, D., Velen, K., Lessells, R., Makgopa, S., Gumede, D., Fielding, K., Grant, A.D., Charalambous, S., & Chetty-Makkan, C. M. (2023). A qualitative exploration into the presence of TB stigmatization across three districts in South Africa. *BMC Public Health, 23*(1), 504. https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-023-15407-2

de Vellis, R. F., & Thorpe, C. T. (2021). *Scale development: Theory and applications*. Sage.

Dheda, K., Perumal, T., Moultrie, H., Perumal, R., Esmail, A., Scott, A. J., Udwadia, Z., Chang, K. C., Peter, J., Pooran, A., von Delft, A., von Delft, D., Martinson, N., Loveday, M., Charalambous, S., Kachingwe, E., Jassat, W., Cohen, C., Tempia, S., … Pai, M. (2022). The intersecting pandemics of tuberculosis and COVID-19: population-level and patient-level impact, clinical presentation, and corrective interventions. *The Lancet. Respiratory Medicine, 10*(6), 603–622. https://doi.org/10.1016/S2213-2600(22)00092-3

DiStefano, M. J., & Schmidt, H. (2016). mHealth for tuberculosis treatment adherence: a framework to guide ethical planning, implementation, and evaluation. *Global Health: Science and Practice, 4*(2), 211–221. doi: 10.9745/GHSP-D-16-00018

Do, D., Garfein, R. S., Cuevas-Mota, J., Collins, K., & Liu, L. (2019). Change in patient comfort using mobile phones following the use of an app to monitor tuberculosis treatment adherence: longitudinal study. *JMIR mHealth and uHealth, 7*(2), e11638. doi: 10.2196/11638

Dogonchi, M., Mohammadzadeh, F., & Moshki, M. (2022). Investigating the relationship between health locus of control and health behaviors: A systematic review. *The Open Public Health Journal, 15*(1). https://doi.org/10.2174/18749445-v15-e2208010

Doherty, A. M., Kelly, J., McDonald, C., O'Dywer, A. M., Keane, J., & Cooney, J. (2013). A review of the interplay between tuberculosis and mental health. General Hospital Psychiatry, 35(4), 398–406. https://doi.org/10.1016/j.genhosppsych.2013.03.018

Donaldson, L. (1992). The Weick stuff: Managing beyond games. *Organization Science, 3*(4), 461–466. https://www.jstor.org/stable/2635110

Donevant, S. B., Estrada, R. D., Culley, J. M., Habing, B., & Adams, S. A. (2018). Exploring app features with outcomes in mHealth studies involving chronic respiratory diseases, diabetes, and hypertension: a targeted exploration of the literature. *Journal of the American Medical Informatics Association*, *25*(10), 1407–1418. doi: 10.1093/jamia/ocy104

Drabarek, D., Anh, N. T., Nhung, N. V., Hoa, N. B., Fox, G. J., & Bernays, S. (2019). Implementation of medication event reminder monitors among patients diagnosed with drug susceptible tuberculosis in rural Viet Nam: A qualitative study. *PLoS One*, *14*(7), e0219891. doi: 10.1371/journal.pone.0219891

Drapeau, A., Marchand, A., & Beaulieu-Prévost, D. (2012). Epidemiology of psychological distress. *Mental Illnesses-Understanding, Prediction and Control, 69*(2), 105-–106. https://doi.org/10.5772/30872

Du, L., Wu, R., Chen, X., Xu, J., Ji, H., & Zhou, L. (2020). Role of treatment adherence, doctor–patient trust, and communication in predicting treatment effects among tuberculosis patients: difference between urban and rural areas. *Patient Preference and Adherence*, 2327–2336. doi: 10.2147/PPA.S277650

Duko, B., Bedaso, A., Ayano, G., & Yohannis, Z. (2019). Perceived stigma and associated factors among patient with tuberculosis, Wolaita Sodo, Ethiopia: Cross-sectional study. *Tuberculosis Research and Treatment*, 2019, 5917537. https://doi.org/10.1155/2019/5917537

Dworkin, M. S., Lee, S., Chakraborty, A., Monahan, C., Hightow-Weidman, L., Garofalo, R., Qato, D. M., Liu, L., & Jimenez, A. (2019). Acceptability, feasibility, and preliminary efficacy of a theory-based relational embodied conversational agent mobile phone intervention to promote HIV medication adherence in young HIV-positive African American MSM. *AIDS Education and Prevention, 31*(1), 17–37. https://doi.org/10.1521/aeap.2019.31.1.17

Dworkin, M. S., Panchal, P., Wiebel, W., Garofalo, R., Haberer, J. E., & Jimenez, A. (2019). A triaged real-time alert intervention to improve antiretroviral therapy adherence among young African American men who have sex with men living with HIV: Focus group findings. *BMC Public Health*, *19*(1), 394. https://link.springer.com/article/10.1186/s12889-019-6689-1

Easthall, C., & Barnett, N. (2017). Using theory to explore the determinants of medication adherence; moving away from a one-size-fits-all approach. *Pharmacy, 5*(3), 50. https://www.mdpi.com/2226-4787/5/3/50

El Alili, M., Vrijens, B., Demonceau, J., Evers, S. M., & Hiligsmann, M. (2016). A scoping review of studies comparing the medication event monitoring system (MEMS) with alternative methods for measuring medication adherence. *British Journal of Clinical Pharmacology, 82*(1), 268–279. https://doi.org/10.1111/bcp.12942

Elliott, R. A., Boyd, M. J., Tanajewski, L., Barber, N., Gkountouras, G., Avery, A. J., Mehta, R., Davies, J. E., Salema, N. E., Craig, C., Latif, A., Waring, J., & Chuter, A. (2020). ‘‘New Medicine Service’’: supporting adherence in people starting a new medication for a long-term condition: 26-week follow-up of a pragmatic randomised controlled trial. *BMJ Quality & Safety, 29*(4), 286–295. https://doi.org/10.1136/bmjqs-2018-009177

El-Muttalut, M., & Khidir Elnimeiri, M. (2017). Factors contributing to non-compliance with treatment among tuberculosis patients-Kassala State-Sudan-2016. *International Journal of Public Health, 6*, 332–338.

Engel, N., Ganesh, G., Patil, M., Yellappa, V., Pant Pai, N., Vadnais, C., & Pai, M. (2015). Barriers to point-of-care testing in India: results from qualitative research across different settings, users and major diseases. *PLoS One, 10*(8), e0135112. https://doi.org/10.1371/journal.pone.0135112

Evans, D., Berhanu, R., Moyo, F., Nguweneza, A., Long, L., & Fox, M. P. (2016). Can short-term use of electronic patient adherence monitoring devices improve adherence in patients failing second-line antiretroviral therapy? Evidence from a pilot study in Johannesburg, South Africa. *AIDS and Behavior, 20*(11), 2717–2728. doi: 10.1007/s10461-016-1417-7

Farmer, K. C. (1999). Methods for measuring and monitoring medication regimen adherence in clinical trials and clinical practice. *Clinical Therapeutics, 21*(6), 1074–1073. https://doi.org/10.1016/S0149-2918(99)80026-5

Fathabadi, J., Izaddost, M., Taghavi, D., Shalani, B., & Sadeghi, S. (2018). The role of irrational health beliefs, health locus of control and health-oriented lifestyle in predicting the risk of diabetes. *Payesh (Health Monitor), 17*(2), 169–178. https://payeshjournal.ir/article-1-56-en.html

Feilzer, M.Y. (2010). Doing mixed methods research pragmatically: Implications for the rediscovery of pragmatism as a research paradigm. *Journal of Mixed Methods Research, 4*(1), 6–16. doi: 10.1177/1558689809349691

Feldman, D. B., & Crandall, C. S. (2007). Dimensions of mental illness stigma: What about mental illness causes social rejection? *Journal of Social and Clinical Psychology, 26*(2), 137–154. https://doi.org/10.1521/jscp.2007.26.2.137

Fernandez, S., Chaplin, W., Schoenthaler, A. M., & Ogedegbe, G. (2008). Revision and validation of the medication adherence self-efficacy scale (MASES) in hypertensive African Americans. *Journal of Behavioral Medicine, 31*, 453–462. doi: 10.1007/s10865-008-9170-7

Fernandez-Lazaro, C. I., García-González, J. M., Adams, D. P., Fernandez-Lazaro, D., Mielgo-Ayuso, J., Caballero-Garcia, A., Moreno Racionero, F., Córdova, A., & Miron-Canelo, J. A. (2019). Adherence to treatment and related factors among patients with chronic conditions in primary care: a cross-sectional study. *BMC Family Practice, 20*(1), 132. https://doi.org/10.1186/s12875-019-1019-3

Fetters, M. D., Curry, L. A., & Creswell, J. W. (2013). Achieving integration in mixed methods designs—principles and practices. *Health Services Research, 48*(6pt2), 2134–2156. https://onlinelibrary.wiley.com/doi/pdf/10.1111/1475-6773.12117

Fielding, N. G. (2012). Triangulation and mixed methods designs: Data integration with new research technologies. *Journal of Mixed Methods Research, 6*(2), 124–136. https://journals.sagepub.com/doi/full/10.1177/1558689812437101

Fischer, F. (1998). Beyond empiricism: policy inquiry in post positivist perspective. *Policy Studies Journal, 26*(1), 129–146. https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1541-0072.1998.tb01929.x

Fiseha, D., & Demissie, M. (2015). Assessment of Directly Observed Therapy (DOT) following tuberculosis regimen change in Addis Ababa, Ethiopia: a qualitative study. *BMC Infectious Di eases, 15*, 1–9. doi: 10.1186/s12879-015-1142-2

Fishman, D. (1999). *The case for pragmatic psychology*. NYU Press.

Forbes, C. A., Deshpande, S., Sorio-Vilela, F., Kutikova, L., Duffy, S., Gouni-Berthold, I., & Hagström, E. (2018). A systematic literature review comparing methods for the measurement of patient persistence and adherence. *Current Medical Research and Opinion, 34*(9), 1613–1625. https://doi.org/10.1080/03007995.2018.1477747

Fowler Jr, F. J., Lloyd, S. J., Cosenza, C. A., & Wilson, I. B. (2016). Coding cognitive interviews: an approach to enhancing the value of cognitive testing for survey question evaluation. *Field Methods, 28*(1), 3–20. https://doi.org/10.1177/1525822X14549921

Franklin, B. D., Abel, G., & Shojania, K. G. (2020). Medication non-adherence: an overlooked target for quality improvement interventions. *BMJ Quality & Safety, 29*(4), 271–273. https://doi.org/10.1136/bmjqs-2019-009984

Free, C., Phillips, G., Watson, L., Galli, L., Felix, L., Edwards, P., Patel, V., & Haines, A. (2013). The effectiveness of mobile-health technologies to improve health care service delivery processes: a systematic review and meta-analysis. *PLoS Medicine, 10*(1), e1001363. https://doi.org/10.1371/journal.pmed.1001363

Frick, M., & Lessem, E. (2018). *Tuberculosis research funding trends, 2005–2017*. New York, NY: Treatment Action Group. http://www.treatmentactiongroup.org/sites/default/files/tb_funding_2018_final.pdf

Gaifer, Z., & Boulassel, M. R. (2019). Comparative analysis of two methods of measuring antiretroviral therapy adherence in HIV-infected Omani patients. *Journal of the International Association of Providers of AIDS Care (JIAPAC), 18*, 2325958219867316. https://journals.sagepub.com/doi/full/10.1177/2325958219867316

Gaito, J. (1980). Measurement scales and statistics: Resurgence of an old misconception. *Psychological Bulletin, 87*(3), 564–567. https://doi.org/10.1037/0033-2909.87.3.564

Gallagher, M. W. (2012) 'Self-efficacy', In V.S. Ramachandran, (Ed.) *Encyclopedia of human behavior*, (2nd ed, pp. 314–320). Elsevier. doi: 10.1016/B978-0-12-375000-6.00312-8

García-Pérez, M. A., & Alcalá-Quintana, R. (2012). On the discrepant results in synchrony judgment and temporal-order judgment tasks: a quantitative model. *Psychonomic Bulletin & Review, 19*, 820–846. https://www.proquest.com/docview/1095372926?pq-origsite=gscholar&fromopenview=true&sourcetype=Scholarly%20Journals

Garfein, R. S., Collins, K., Muñoz, F., Moser, K., Cerecer-Callu, P., Raab, F., Rios, P., Flick, A., Zúñiga, M.L., Cuevas-Mota, J., & Liang, K. (2015). Feasibility of tuberculosis treatment monitoring by video directly observed therapy: a binational pilot study. *The International Journal of Tuberculosis and Lung Disease, 19*(9), 1057–1064. https://doi.org/10.5588/ijtld.14.0923

Gashu, K. D., Gelaye, K. A., & Tilahun, B. (2021). Adherence to TB treatment remains low during continuation phase among adult patients in Northwest Ethiopia. *BMC Infectious Diseases, 21*(1), 725. https://doi.org/10.1186/s12879-021-06428-6

Gatchel, R. J., Oordt, M. S., & Oordt, M. S. (2003). *Clinical health psychology and primary care: Practical advice and clinical guidance for successful collaboration* (pp. xiv–263). American Psychological Association. doi:10.1037/1091-7527.22.2.239

Gebremariam, R. B., Wolde, M., & Beyene, A. (2021). Determinants of adherence to anti-TB treatment and associated factors among adult TB patients in Gondar city administration, Northwest, Ethiopia: based on health belief model perspective. *Journal of Health,*

Population and Nutrition, 40, 1–10. https://link.springer.com/article/10.1186/s41043-021-00275-6

Gebreweld, F. H., Kifle, M. M., Gebremicheal, F. E., Simel, L. L., Gezae, M. M., Ghebreyesus, S. S., Mengsteab, Y.T., & Wahd, N. G. (2018). Factors influencing adherence to tuberculosis treatment in Asmara, Eritrea: a qualitative study. *Journal of Health, Population and Nutrition, 37*(1), 1. doi: 10.1186/s1043-017-0132-y

George, M., Abboud, S., Pantalon, M. V., Sommers, M. L. S., Mao, J., & Rand, C. (2016). Changes in clinical conversations when providers are informed of asthma patients' beliefs about medication use and integrative medical therapies. *Heart & Lung, 45*(1), 70-78. http://dx.doi.org/10.1016/j.hrtlng.2015.11.002.

Gephart, R. (1999). Stories of achievements: Narrative features of organizational performance. *ILR Review*, *52*(3), 486–488. doi:10.2307/2525150

Glanz, K., Rimer, B. K., & Viswanath, K. (2008). Theory, research, and practice in health behavior and health education. In K. Glanz, B. K. Rimer, & K. Viswanath (Eds.), *Health behavior and health education: Theory, research, and practice* (4th ed., pp. 23–40). Jossey-Bass.

Gluck S. (2019). What is stigma? In: HealthyPlace. https://www.healthyplace.com/stigma/stand-up-for-mental-health/what-is-stigma.

Goffman, E. (1963). *Stigma: Notes on the management of spoiled identity*. Prentice Hall.

Golden, S. D., & Earp, J. A. (2012). Social ecological approaches to individuals and their contexts: twenty years of health education & behavior health promotion interventions. Health education & behavior: the official publication of the Society for Public Health Education, 39(3), 364–372. https://doi.org/10.1177/1090198111418634

Gomes, V. F., Wejse, C., Oliveira, I., Andersen, A., Vieira, F. J., Carlos, L. J., Vieira, C. S., Aaby, P., & Gustafson, P. (2011). Adherence to isoniazid preventive therapy in children exposed to tuberculosis: a prospective study from Guinea-Bissau. *The International Journal of Tuberculosis and Lung Disease*,*15*(12), 1637–1643. https://doi.org/10.5588/ijtld.10.0558

González-Castro, J. L., Ubillos-Landa, S., Puente-Martínez, A., & Gracia-Leiva, M. (2021). Perceived vulnerability and severity predict adherence to COVID-19 protection measures: The mediating role of instrumental coping. *Frontiers in Psychology, 12*, 674032. https://doi.org/10.3389/fpsyg.2021.674032

Goswami, A., & Dutta, S. (2015). Gender differences in technology usage—A literature review. *Open Journal of Business and Management*, *4*(1), 51–59. doi: 10.4236/ojbm.2016.41006

Gravetter, F. J., & Forzano, L. A. B. (2006). *Research methods for the behavioral sciences*. Thomson/Wadsworth.

Gravetter, F. J., & Forzano, L. B. (2012). *Research methods for the behavioural sciences*. Wadsworth Cengage Learning.

Grunfeld, E. A., Hunter, M. S., Sikka, P., & Mittal, S. (2005). Adherence beliefs among breast cancer patients taking tamoxifen. *Patient Education and Counseling*, *59*(1), 97–102. doi: 10.1016/j.pec.2004.10.005

Guba, E. G. (1990). *The paradigm dialog.* Sage

Guba, E. G., & Lincoln, Y. S. (1994), Competing paradigms in qualitative research. In Denzin, N. K., & Y. S. Lincoln (Eds.), *Handbook of qualitative research.* Sage

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. *Handbook of qualitative research*, *2*(163–194), 105. Sage.

Guetterman, T. C., & Fetters, M. D. (2018). Two methodological approaches to the integration of mixed methods and case study designs: A systematic review. *American Behavioral Scientist, 62*(7), 900–918. https://doi.org/10.1177/0002764218772641

Guetterman, T. C., Fetters, M. D., & Creswell, J. W. (2015). Integrating quantitative and qualitative results in health science mixed methods research through joint displays. *The Annals of Family Medicine*, *13*(6), 554–561.

Guzman, K., Crowder, R., Leddy, A., Maraba, N., Jennings, L., Ahmed, S., Sultana, S., Onjare, B., Shilugu, L., Alacapa, J., Levy, J. & Khan, A. (2023). Acceptability and feasibility of digital adherence technologies for drug-susceptible tuberculosis treatment supervision: A meta-analysis of implementation feedback. *PLoS Digital Health*, *2*(8), e0000322. https://journals.plos.org/digitalhealth/article?id=10.1371/journal.pdig.0000322

Haase, J., Farris, K. B., & Dorsch, M. P. (2017). Mobile applications to improve medication adherence. Telemedicine and e-Health, 23(2), 75–79. https://doi.org/10.1089/tmj.2015.0227

Haberer, J. E., Musiimenta, A., Atukunda, E. C., Musinguzi, N., Wyatt, M. A., Ware, N. C., & Bangsberg, D. R. (2016). Short message service (SMS) reminders and real-time adherence monitoring improve antiretroviral therapy adherence in rural Uganda. *AIDS (London, England)*, *30*(8), 1295. doi: 10.1097/QAD.0000000000001021

Haberer, J. E., Musinguzi, N., Tsai, A. C., & Boum, Y. (2017). Real-time electronic adherence monitoring plus follow-up improves adherence compared to standard electronic adherence monitoring. *AIDS (London, England)*, *31*(1), 169. doi: 10.1097/QAD.0000000000001310

Haberer, J. E., & Subbaraman, R. (2020). Digital technology for tuberculosis medication adherence: promise and peril. *Annals of the American Thoracic Society*, *17*(4), 421–423. doi: 10.1513/AnnalsATS.202001-027ED

Haberer, J. E., Baijuka, R., Tumuhairwe, J. B., Tindimwebwa, E. B., Tinkamanyire, J., Tuhanamagyezi, E., Musoke, L., Garrison, L.E., DelSignore, M., Musinguzi, N., & Asiimwe, S. (2022). Implementation of electronic adherence monitors and associated interventions for routine HIV antiretroviral therapy in Uganda: promising findings. *Frontiers in Digital Health*, *4*, 899643. https://www.frontiersin.org/journals/digitalhealth/articles/10.3389/fdgth.2022.899643/full

Haberer, J. E., Kiwanuka, J., Nansera, D., Muzoora, C., Hunt, P. W., So, J., O'Donnell, M., Siedner, M., Martin, J.N., & Bangsberg, D. R. (2013). Real-time adherence monitoring of antiretroviral therapy among HIV-infected adults and children in rural Uganda. *AIDS (London, England)*, *27*(13). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3868644/

Hairaty, K., Sadeghmoghadam, L., Alami, A., & Moshki, M. (2019). Effect of education based on health locus of control theory on health literacy among older adult. Internal Medicine Today, 25(1), 37-42. https://imtj.gmu.ac.ir/article-1-2859-en.html

Hamine, S., Gerth-Guyette, E., Faulx, D., Green, B. B., & Ginsburg, A. S. (2015). Impact of mHealth chronic disease management on treatment adherence and patient outcomes: A systematic review. *Journal of Medical Internet Research*, *17*(2). doi: 10.2196/jmir.3951

Hashemian, M., Fallahi, A., Akaberi, A., Asadi, Z. S., Khosrorad, R., & Solimanian, A. (2015). Relationship of health locus of control with attitude toward breast cancer among women with family positive history of breast cancer in Sabzevar city (2014). *The Iranian Journal of Obstetrics, Gynecology and Infertility*, *18*(166.165), 9–15. https://ijogi.mums.ac.ir/article_5842_en.html

Hasker, E., Khodjikhanov, M., Sayfiddinova, S., Rasulova, G., Yuldashova, U., Uzakova, G., Butabekov, I., Veen, J., van der Werf, M.J., & Lefevre, P. (2010). Why do tuberculosis patients default in Tashkent City, Uzbekistan? A qualitative study. *The International Journal of Tuberculosis and Lung Disease*, *14*(9), 1132–1139. https://www.ingentaconnect.com/content/iuatld/ijtld/2010/00000014/00000009/art00011

Hassard, S., Ronald, A., & Angella, K. (2017). Patient attitudes towards community-based tuberculosis DOT and adherence to treatment in an urban setting; Kampala, Uganda. *The Pan African Medical Journal*, *27*(1). https://doi.org/10.11604/pamj.2017.27.1.11119

Hatzipapas, I., Janse van Rensburg, E., & Visser, M. (2017). Laughter therapy as an intervention to promote psychological well-being of volunteer community care workers working with HIV-affected families. *SAHARA: Journal of Social Aspects of HIV/AIDS Research Alliance*, *14*(1), 202–212. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5706473/

Haynes-Brown, T. K., & Fetters, M. D. (2021). Using joint display as an analytic process: an illustration using bar graphs joint displays from a mixed-methods study of how beliefs shape secondary school teachers' use of technology. *International Journal of Qualitative Methods*, *20*, 1609406921993286. https://journals.sagepub.com/doi/full/10.1177/1609406921993286

Heale, R., & Twycross, A. (2015). Validity and reliability in quantitative studies. *Evidence-based Nursing*, *18*(3), 66–67. doi: 10.1136/eb-2015-102129

Health Professions Council of South Africa. (2016). *Guidelines for good practice in the health care professions: General ethical guidelines for health care professions*. https://www.hpcsa.co.za/Uploads/Professional_Practice/Conduct%20%26%20Ethics/Booklet%201%20Guidelines%20for%20Good%20Practice%20%20September%202016.pdf

Henning, E., van Rensburg, W., & Smit, B. (2004). *Finding your way in qualitative research: A beginner's guide*. Van Schaik.

Heo, S., Kim, J., Shim, J. L., Barbe, T., Black, V., & Lee, M. O. (2021). Experiences of and factors associated with dietary sodium adherence in heart failure from patients' and their caregivers' perspectives: A qualitative study. *Geriatric Nursing*, *42*(5), 1190–1197. https://www.sciencedirect.com/science/article/abs/pii/S0197457221002597

Herrero, M. B., Ramos, S., & Arrossi, S. (2015). Determinants of non-adherence to tuberculosis treatment in Argentina: Barriers related to access to treatment. *Revista Brasileira de Epidemiologia = Brazilian Journal of Epidemiology*, *18*(2), 287–298. https://doi.org/10.1590/1980-5497201500020001

Hess, L. M., Raebel, M. A., Conner, D. A., & Malone, D. C. (2006). Measurement of adherence in pharmacy administrative databases: Aa proposal for standard definitions and preferred measures. *The Annals of Pharmacotherapy*, *40*(7–8), 1280–1288. https://doi.org/10.1345/aph.1H018

Hibbard, J. H., & Greene, J. (2013). What the evidence shows about patient activation: better health outcomes and care experiences; fewer data on costs. *Health Affairs*, *32*(2), 207–214. https://www.healthaffairs.org/doi/full/10.1377/hlthaff.2012.1061

Hincapie, A. L., Gupta, V., Brown, S. A., & Metzger, A. H. (2019). Exploring perceived barriers to medication adherence and the use of mobile technology in underserved patients with

chronic conditions. *Journal of Pharmacy Practice, 32*(2), 147–153. https://doi.org/10.1177/0897190017744953

Hochbaum, G. M. (1958). *Public participation in medical screening programs: A socio-psychological study* (No. 572). US Department of Health, Education, and Welfare, Public Health Service, Bureau of State Services, Division of Special Health Services, Tuberculosis Program.

Holloway, A., & Watson, H. E. (2002). Role of self-efficacy and behaviour change. *International Journal of Nursing Practice, 8*(2), 106–115. https://doi.org/10.1046/j.1440-172x.2002.00352.x

Huang, C. Y., Nguyen, P. A., Clinciu, D. L., Hsu, C. K., Lu, J. R., Yang, H. C., Wu, C. C., Tsai, W. C., Chou, Y. C., Kuo, T. B. J., Chang, P. L., Jian, W. S., & Li, Y. J. (2017). A personalized medication management platform (PMMP) to improve medication adherence: A randomized control trial. *Computer Methods and Programs in Biomedicine, 140*, 275–281. https://doi.org/10.1016/j.cmpb.2016.12.012

Huang, L., Li, L., Zhang, Y., Li, H., Li, X., & Wang, H. (2013). Self-efficacy, medication adherence, and quality of life among people living with HIV in Hunan Province of China: a questionnaire survey. *Journal of the Association of Nurses in AIDS Care*, *24*(2), 145–153. https://www.sciencedirect.com/science/article/abs/pii/S1055329012001021

Hudson, L. A., & Ozanne, J. L. (1988). Alternative ways of seeking knowledge in consumer research. *Journal of Consumer Research, 14*(4), 508–521. https://www.jstor.org/tc/accept?origin=%2Fstable%2Fpdf%2F2489157.pdf&is_image=False

Hüther, J., von Wolff, A., Stange, D., Härter, M., Baehr, M., Dartsch, D. C., & Kriston, L. (2013). Incomplete medication adherence of chronically ill patients in German primary care. *Patient Preference and Adherence,7*, 237–244. https://doi.org/10.2147/PPA.S38373

Ifebunandu, N. A., & Ukwaja, K. N. (2012). Tuberculosis treatment default in a large tertiary care hospital in urban Nigeria: prevalence, trend, timing and predictors. *Journal of Infection and Public Health, 5*(5), 340–345. https://doi.org/10.1016/j.jiph.2012.06.002

Islam, K. F., Awal, A., Mazumder, H., Munni, U. R., Majumder, K., Afroz, K., Tabassum, M.N., & Hossain, M. M. (2023). Social cognitive theory-based health promotion in primary care practice: A scoping review. *Heliyon, 9*(4). doi: 10.1016/j.heliyon.2023.e14889

Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using mixed-methods sequential explanatory design: From theory to practice. *Field Methods, 18*(1), 3–20. https://journals.sagepub.com/doi/abs/10.1177/1525822x05282260

Izudi, J., Semakula, D., Sennono, R., Tamwesigire, I. K., & Bajunirwe, F. (2019). Treatment success rate among adult pulmonary tuberculosis patients in sub-Saharan Africa: a systematic review and meta-analysis. *BMJ Open, 9*(9), e029400. https://doi.org/10.1136/bmjopen-2019-029400

Jeihooni, A. K., Hidarnia, A., Kaveh, M. H., Hajizadeh, E., & Askari, A. (2016). Application of the health belief model and social cognitive theory for osteoporosis preventive nutritional behaviors in a sample of Iranian women. *Iranian Journal of Nursing and Midwifery Research*, *21*(2), 131–141. doi: 10.4103/1735-9066.178231

Jensen, F. F., Håkansson, K. E., Overgaard Nielsen, B., Weinreich, U. M., & Ulrik, C. S. (2021). Self-reported vs. objectively assessed adherence to inhaled corticosteroids in asthma. *Asthma Research and Practice, 7*(1), 7. https://asthmarp.biomedcentral.com/articles/10.1186/s40733-021-00072-2#citeas

Jeranji, T. (2021). Government reveals plans to restore TB services in South Africa. *Daily Maverick.* https://www.dailymaverick.co.za/article/2021-12-15-government-reveals-plans-to-restore-tb-services-in-south-africa/

Jerant, A., DiMatteo, R., Arnsten, J., Moore-Hill, M., & Franks, P. (2008). Self-report adherence measures in chronic illness: retest reliability and predictive validity. *Medical Care*, *46*(11), 1134–1139. doi: 10.1097/MLR.0b013e31817924e4

Jilcha Sileyew, K. (2020). Research Design and Methodology. IntechOpen. doi: 10.5772/intechopen.85731

Johnson, R. B., & Christensen, L. (2019). *Educational research: Quantitative, qualitative, and mixed approaches*. Sage publications.

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, *33*(7), 14-26. https://doi.org/10.3102/0013189X033007014

Joho, A. A. (2012). *Factors affecting treatment compliance among hypertension patients in three district hospitals-Dar es Salaam* (Doctoral dissertation, Muhimbili University of Health and Allied Sciences). https://www.scirp.org/reference/referencespapers?referenceid=2094137

Juan, G., Lloret, T., Perez, C., Lopez, P., Navarro, R., Ramón, M., Cortijo, J., & Morcillo, E. J. (2006). Directly observed treatment for tuberculosis in pharmacies compared with self-administered therapy in Spain. *The International Journal of Tuberculosis and Lung Disease, 10*(2), 215–221.

Kahere, M., Hlongwana, K., & Ginindza, T. (2022). Exploring patients' lived experience on the barriers to accessing low back pain health services. *African Journal of Primary Health Care & Family Medicine, 14*(1), e1–e10. https://doi.org/10.4102/phcfm.v14i1.3523

Kamaradova, D., Latalova, K., Prasko, J., Kubinek, R., Vrbova, K., Mainerova, B., Cinculova, A., Ociskova, M., Holubova, M., Smoldasova, J., & Tichackova, A. (2016). Connection between self-stigma, adherence to treatment, and discontinuation of medication. *Patient Preference and Adherence, 10,* 1289–1298. https://doi.org/10.2147/PPA.S99136

Kamran, A., Ahari, S. S., Biria, M., Malpour, A., & Heydari, H. (2014). Determinants of patient's adherence to hypertension medications: application of health belief model among rural patients. *Annals of Medical and Health Sciences Research, 4*(6), 922–927. https://www.ajol.info/index.php/amhsr/article/view/112436

Kane, J. C., Elafros, M. A., Murray, S. M., Mitchell, E. M., Augustinavicius, J. L., Causevic, S., & Baral, S. D. (2019). A scoping review of health-related stigma outcomes for high-burden diseases in low-and middle-income countries. *BMC Medicine, 17,* 1–40. https://bmcmedicine.biomedcentral.com/articles/10.1186/s12916-019-1250-8

Kaplan, B., & Maxwell, J. A. (2005). Qualitative research methods for evaluating computer information systems. In *Evaluating the organizational impact of healthcare information systems* (pp. 30–55). Springer New York.

Kara S. (2022). General self-efficacy and hypertension treatment adherence in Algerian private clinical settings. *Journal of Public Health in Africa, 13*(3), 2121. https://doi.org/10.4081/jphia.2022.2121

Karumbi, J., & Garner, P. (2015). Directly observed therapy for treating tuberculosis. *Cochrane Database of Systematic Reviews*, (5). https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD003343.pub4/full

Karunamuni, N., Imayama, I., & Goonetilleke, D. (2021). Pathways to well-being: Untangling the causal relationships among biopsychosocial variables. *Social Science & Medicine, 272,* 112846. https://doi.org/10.1016/j.socscimed.2020.112846

Kasahun, A. E., Sendekie, A. K., Mekonnen, G. A., Sema, F. D., Kemal, L. K., & Abebe, R. B. (2022). Impact of personal, cultural and religious beliefs on medication adherence among

patients with chronic diseases at university hospital in Northwest Ethiopia. *Patient Preference and Adherence*, 1787–1803. doi: 10.2147/PPA.S370178

Kastien-Hilka, T., Rosenkranz, B., Schwenkglenks, M., Bennett, B. M., & Sinanovic, E. (2017). Association between health-related quality of life and medication adherence in pulmonary tuberculosis in South Africa. *Frontiers in Pharmacology, 8*, 919. https://www.frontiersin.org/articles/10.3389/fphar.2017.00919/full

Kay, M., Santos, J., & Takane, M. (2011). mHealth: New horizons for health through mobile technologies. *World Health Organization, 64*(7), 66–71.

Kayigamba, F. R., Bakker, M. I., Mugisha, V., de Naeyer, L., Gasana, M., Cobelens, F., & van der Loeff, M. S. (2013). Adherence to tuberculosis treatment, sputum smear conversion and mortality: a retrospective cohort study in 48 Rwandan clinics. *PloS One, 8*(9), e73501. https://doi.org/10.1371/journal.pone.0073501

Kimberlin, C. L., & Winterstein, A. G. (2008). Validity and reliability of measurement instruments used in research. *American Journal of Health-system Pharmacy : AJHP : 65*(23), 2276–2284. https://doi.org/10.2146/ajhp070364

Kini, V., & Ho, P. M. (2018). Interventions to improve medication adherence: A review. *Jama*, *320*(23), 2461–2473. doi: 10.1001/jama.2018.19271

Kirscht, J. P. (1974). he health belief model and illness behavior. *Health Education Monographs*, *2*(4), 387–408. https://journals.sagepub.com/doi/abs/10.1177/109019817400200406

Kizito, S., Nakalega, R., Nampijja, D., Atuheire, C., Amanya, G., Kibuuka, E., Nansumba, H., Obuku, E., Kalyango, J., & Karamagi, C. (2022). High burden of pulmonary tuberculosis and missed opportunity to initiate treatment among children in Kampala, Uganda. *African Health Sciences*, *22*(4), 607–618. doi: 10.4314/ahs.v22i4.66

Kjos, A. L., Vaughan, A. G., & Bhargava, A. (2019). Impact of a mobile app on medication adherence and adherence-related beliefs in patients with type 2 diabetes. *Journal of the American Pharmacists Association, 59*(2S), S44–S51.e3. https://doi.org/10.1016/j.japh.2018.12.012

Kleinsinger, F. (2018). The unmet challenge of medication nonadherence. *The Permanente Journal, 22*. doi: 10.7812/TPP/18-033

Kock, N., Gallivan, M. J., & DeLuca, D. (2008). Furthering information systems action research: a post-positivist synthesis of four dialectics. *Journal of the Association for Information Systems, 9*(2), 4. doi: 10.17705/1jais.00150

Korstjens, I., & Moser, A. (2018). Series: Practical guidance to qualitative research. Part 4: Trustworthiness and publishing. *European Journal of General Practice*, *24*(1), 120–124. doi:10.1080/13814788.2017.1375092

Koss, C. A., Hosek, S. G., Bacchetti, P., Anderson, P. L., Liu, A. Y., Horng, H., Benet, L.Z., Kuncze, K., Louie, A., Saberi, P., Wilson, C. M., & Gandhi, M. (2018). Comparison of measures of adherence to human immunodeficiency virus preexposure prophylaxis among adolescent and young men who have sex with men in the United States. *Clinical Infectious Diseases*, *66*(2), 213–219. https://academic.oup.com/cid/article/66/2/213/4093107

Kotrlik, J. W. K. J. W., & Williams, H. A. W. H. A. (2003). The incorporation of effect size in information technology, learning, information technology, learning, and performance research and performance research. *Information Technology, Learning, and Performance Journal*, *21*(1), 1. https://www.proquest.com/docview/219841023?pq-origsite=gscholar&fromopenview=true&sourcetype=Scholarly%20Journals

Kruk, M. E., Gage, A. D., Arsenault, C., Jordan, K., Leslie, H. H., Roder-DeWan, S., Adeyi, O., Barker, P., Daelmans, B., Doubova, S. V., English, M., García-Elorrio, E., Guanais, F., Gureje, O., Hirschhorn, L. R., Jiang, L., Kelley, E., Lemango, E. T., Liljestrand, J., Malata, A., … Pate, M. (2018). High-quality health systems in the Sustainable Development Goals era: Time for a revolution. *The Lancet Global Health*, *6*(11), e1196–e1252. https://doi.org/10.1016/S2214-109X(18)30386-3

Kruk, M. E., Pate, M., & Mullan, Z. (2017). Introducing The Lancet Global Health Commission on high-quality health systems in the SDG era. *The Lancet. Global Health*, *5*(5), e480–e481. https://doi.org/10.1016/S2214-109X(17)30101-8

Kulkarni, P., Akarte, S., Mankeshwar, R., Bhawalkar, J., Banerjee, A., & Kulkarni, A. (2013). Non-adherence of new pulmonary tuberculosis patients to anti-tuberculosis treatment. *Annals of Medical and Health Sciences Research*, *3*(1), 67–74. https://doi.org/10.4103/2141-9248.109507

Kusnanto, H., Agustian, D., & Hilmanto, D. (2018). Biopsychosocial model of illnesses in primary care: A hermeneutic literature review. *Journal of Family Medicine and Primary Care*, *7*(3), 497–500. doi: 10.4103/jfmpc.jfmpc_145_17

Kutney-Lee, A., Sloane, D. M., Bowles, K. H., Burns, L. R., & Aiken, L. H. (2019). Electronic health record adoption and nurse reports of usability and quality of care: The role of work environment. *Applied Clinical Informatics*, *10*(1), 129–139. doi: 10.1055/s-0039-1678551

Kuznetsov, V. N., Grjibovski, A. M., Mariandyshev, A. O., Johansson, E., Enarson, D. A., & Bjune, G. A. (2013). Hopelessness as a basis for tuberculosis diagnostic delay in the Arkhangelsk region: a grounded theory study. *BMC Public Health, 13,* 1–11. doi: 10.1186/1471-2458-13-712

Kvarnström, K., Westerholm, A., Airaksinen, M., & Liira, H. (2021). Factors contributing to medication adherence in patients with a chronic condition: a scoping review of qualitative research. *Pharmaceutics*, *13*(7), 1100. doi: 10.3390/pharmaceutics13071100

Kwame, A., & Petrucka, P.M. (2021). A literature-based study of patient-centered care and communication in nurse-patient interactions: barriers, facilitators, and the way forward. BMC Nursing, 20 (1), 158. https://doi.org/10.1186/s12912-021-00684-2

Kwapong, G. D., Boateng, D., Agyei-Baffour, P., & Addy, E. A. (2014). Health service barriers to HIV testing and counseling among pregnant women attending Antenatal Clinic: A cross-sectional study. *BMC Health Services Research, 14*, 1–10. https://doi.org/10.1186/1472-6963-14-267

KwaZulu-Natal Department of Health, (2001, July 18). *Definitions of health facilities*. https://www.kznhealth.gov.za/definitions.htm

Lam, W. Y., & Fresco, P. (2015). Medication adherence measures: An overview. *Biomed Research International,* 2015, 217047. https://doi.org/10.1155/2015/217047

LaMorte, W. W. (2022). *The transtheoretical model (stages of change).* Boston University School of Public Health. https://sphweb.bumc.bu.edu/otlt/mphmodules/sb/behavioralchangetheories/BehavioralChangeTheories6.html

Laranjo, L. (2016). Social media and health behavior change. In *Participatory health through social media* (pp. 83–111). Academic Press. https://www.sciencedirect.com/science/article/abs/pii/B9780128092699000062

Leddy, A., Ggita, J., Berger, C. A., Kityamuwesi, A., Sanyu, A. N., Tinka, L. K., Crowder, R., Turyahabwe, S., Katamba, A., & Cattamanchi, A. (2023). Barriers and facilitators to implementing a digital adherence technology for tuberculosis treatment supervision in Uganda: qualitative study. *Journal of Medical Internet Research, 25*, e38828. doi: 10.2196/38828

Lester, R., Park, J. J., Bolten, L. M., Enjetti, A., Johnston, J. C., Schwartzman, K., & von Delft, A. (2019). Mobile phone short message service for adherence support and care of patients with tuberculosis infection: Evidence and opportunity. *Journal of Clinical Tuberculosis and Other Mycobacterial Diseases*, *16*, 100108. https://www.sciencedirect.com/science/article/pii/S240557941830041X

Leventhal, H., Brissette, I., & Leventhal, E. A. (2003). The common-sense model of self-regulation of health and illness. In L. D. Cameron & H. Leventhal (Eds.), *The self-regulation of health and illness behaviour* (pp. 42–65). Routledge.

Leventhal, H., Forster, R., & Leventhal, E. (2007). Self-Regulation of Health Threats, Affect, and the Self: Lessons from Older Adults. In C. M. Aldwin, C. L. Park, & A. Spiro III (Eds.), *Handbook of health psychology and aging* (pp. 341–366). The Guilford Press.

Leventhal, H., Meyer, D., & Nerenz, D. (1980). The common sense model of illness danger. In Rachman, S.(Ed.) *Medical psychology. Contributions to medical psychology*, (pp.7–30.)

Leventhal, H., Phillips, L. A., & Burns, E. (2016). The common-sense model of self-regulation (CSM): Aa dynamic framework for understanding illness self-management. *Journal of Behavioral Medicine, 39*(6), 935–946. https://doi.org/10.1007/s10865-016-9782-2

Lewis, J. L., & Sheppard, S. R. (2006). Culture and communication: can landscape visualization improve forest management consultation with indigenous communities? *Landscape and Urban Planning*, *77*(3), 291–313. https://doi.org/10.1016/j.landurbplan.2005.04.004

Lim, R. K., Semitala, F. C., Atuhumuza, E., Sabiti, L., Namakula-Katende, J., Muyindike, W.R., Kamya, M. R., Dowdy, D., & Cattamanchi, A. (2021) Patient choice improves self-efficacy and intention to complete tuberculosis preventive therapy in a routine HIV program setting in Uganda. *PLoS One, 16*(2): e0246113. https://doi.org/10.1371/journal.pone.0246113

Linn, A. J., Vervloet, M., van Dijk, L., Smit, E. G., & Van Weert, J. C. (2011). Effects of eHealth interventions on medication adherence: a systematic review of the literature. *Journal of Medical Internet Research, 13*(4), e103. doi: 10.2196/jmir.1738

Liu, C., Tham, C. W., De Roza, J., Chong, B. Y., Koh, Y. L., & Tan, N. C. (2020). The association between beliefs and adherence to inhaled controller medication among older adults with asthma: a cross-sectional study in primary care. *Patient Preference and Adherence,* 1351–1359. https://www.tandfonline.com/doi/full/10.2147/PPA.S266871

Liu, S., Feng, W., Chhatbar, P. Y., Liu, Y., Ji, X., & Ovbiagele, B. (2017). Mobile health as a viable strategy to enhance stroke risk factor control: A systematic review and meta-analysis.

Journal of the Neurological Sciences, 378, 140–145. https://doi.org/10.1016/j.jns.2017.04.050

Liu, X., Blaschke, T., Thomas, B., De Geest, S., Jiang, S., Gao, Y., Li, X., Buono, E.W., Buchanan, S., Zhang, Z., & Huan, S. (2017). Usability of a medication event reminder monitor system (MERM) by providers and patients to improve adherence in the management of tuberculosis. *International Journal of Environmental Research and Public Health, 14*(10), 1115. https://doi.org/10.3390/ijerph14101115

Liu, X., Thompson, J., Dong, H., Sweeney, S., Li, X., Yuan, Y., Wang, X., He, W., Thomas, B., Xu, C., Hu, D., & Zhao, Y. (2023). Digital adherence technologies to improve tuberculosis treatment outcomes in China: a cluster-randomised superiority trial. *The Lancet Global Health*, *11*(5), e693-e703. https://www.thelancet.com/journals/langlo/article/PIIS2214-109X(23)00068-2/fulltext?uuid=uuid%3A4cf29ba6-00b1-40a4-a69f-69af8da743bf

Luthuli, M. Q., & John-Langba, J. (2024). The moderating role of HIV stigma on the relationship between perceived social support and antiretroviral therapy adherence self-efficacy among adult PLHIV in South Africa. *Journal of the International Association of Providers of AIDS Care (JIAPAC), 23*, 23259582241228743. doi:10.1177/23259582241228743

Maciel, E. L., Silva, A. P., Meireles, W., Fiorotti, K., Hadad, D. J., & Dietze, R. (2008). Directly observed therapy using home-based supervisors for treating tuberculosis in Vitória, Brazil. *Brazilian Journal of Pulmonology*, *34*(7), 506–513. https://doi.org/10.1590/s1806-37132008000700011

Mackenzie, N., & Knipe, S. (2006). Research dilemmas: Paradigms, methods and methodology. *Issues in Educational Research*, *16*(2), 193–205. http://www.iier.org.au/iier16/mackenzie.html

Mahat, G., Scoloveno, M. A., & Scoloveno, R. (2016). HIV/AIDS knowledge, self-efficacy for limiting sexual risk behavior and parental monitoring. *Journal of Pediatric Nursing, 31*(1), e63-e69. https://www.sciencedirect.com/science/article/abs/pii/S0882596315002213

Manyazewal, T., Woldeamanuel, Y., Getinet, T., Hoover, A., Bobosha, K., Fuad, O., Getahun, B., Fekadu, B., Holand, D. P., & Marconi, V. C. (2023). Patient-reported usability and satisfaction with electronic medication event reminder and monitor device for tuberculosis: a multicentre, randomised controlled trial. *EClinical Medicine*, *56*. https://www.thelancet.com/journals/eclinm/article/PIIS2589-5370(22)00549-1/fulltext

Maphumulo, W. T., & Bhengu, B. R. (2019). Challenges of quality improvement in the healthcare of South Africa post-apartheid: A critical review. *Curationis*, *42*(1), 1–9. doi: 10.4102/curationis.v42i1.1901

Marahatta, S. B., Yadav, R. K., Giri, D., Lama, S., Rijal, K. R., Mishra, S. R., Shrestha, A., Bhattrai, P.R., Mahato, R.K., & Adhikari, B. (2020). Barriers in the access, diagnosis and treatment completion for tuberculosis patients in central and western Nepal: A qualitative study among patients, community members and health care workers. *PloS One*, *15*(1), e0227293. doi: 10.1371/journal.pone.0227293

Martin, J. (2019). Deconstructing organizational taboos: The suppression of gender conflict in organizations. In *Postmodern management theory* (pp. 273–293). Routledge.

Martono, M., Akhyar, M., Pamungkasari, E. P., & Lestari, A. (2023). Results of professional interventions to improve medication adherence based on health beliefs and important determinants of tuberculosis medication: a systematic review. *European Review for Medical & Pharmacological Sciences*, *27*(24). doi: 10.26355/eurrev_202312_34778

Martos-Méndez, M. J. (2015). Self-efficacy and adherence to treatment: the mediating effects of social support. *Journal of Behavior, Health & Social Issues*, *7*(2), 19–29. https://www.sciencedirect.com/science/article/pii/S2007078017300020

Matakanye, H., Tshitangano, T. G., Mabunda, J. T., & Maluleke, T. X. (2021). Knowledge, beliefs, and perceptions of TB and its treatment amongst TB patients in the Limpopo province, South Africa. *International Journal Of Environmental Research and Public Health, 18*(19), 10404. https://doi.org/10.3390/ijerph181910404

Mascarenhas, A. (2022). Researchers call for real-time tuberculosis data like Covid-19 dashboards. *The Indian Express*. https://indianexpress.com/article/cities/pune/researchers-call-for-real-time-tuberculosis-data-like-covid-19-dashboards-7852581/

Mason, M., Cho, Y., Rayo, J., Gong, Y., Harris, M., & Jiang, Y. (2022). Technologies for medication adherence monitoring and technology assessment criteria: Narrative review. *JMIR mHealth and uHealth*, *10*(3), e35157. https://doi.org/10.2196/35157

Matakanye, H., & Grace Tshitangano, T. (2024). Enhancing TB treatment adherence through the application of the Behaviour Change Wheel. Cogent Public Health, 11(1). https://doi.org/10.1080/27707571.2024.2376942

Maxcy, S. J. (2003). Pragmatic threads in mixed methods research in social sciences: An emerging theory in support of practice. *Handbook of mixed methods in social and behavioral research*, 51-89. Sage.

Maxwell, J. (1992). Understanding and validity in qualitative research. *Harvard Educational Review, 62*(3), 279–301. https://doi.org/10.17763/haer.62.3.8323320856251826

Maxwell, J.A. (1996). *Qualitative research design: An interactive approach*. Sage.

McAndrew, L., Schneider, S. H., Burns, E., & Leventhal, H. (2007). Does patient blood glucose monitoring improve diabetes control? A systematic review of the literature. *The Diabetes Educator, 33*(6), 991–1013. https://doi.org/10.1177/0145721707309807

McLaren, Z. M., Milliken, A. A., Meyer, A. J., & Sharp, A. R. (2016). Does directly observed therapy improve tuberculosis treatment? More evidence is needed to guide tuberculosis policy. *BMC Infectious Diseases, 16*(1), 537. https://doi.org/10.1186/s12879-016-1862-y

Méda, Z. C., Lin, Y. T., Sombié, I., Maré, D., Morisky, D. E., & Chen, Y. M. A. (2014). Medication-adherence predictors among patients with tuberculosis or human immunodeficiency virus infection in Burkina Faso. *Journal of Microbiology, Immunology and Infection, 47*(3), 222-232. https://doi.org/10.1016/j.jmii.2013.05.001

Mekonnen, H. S., & Azagew, A. W. (2018). Non-adherence to anti-tuberculosis treatment, reasons and associated factors among TB patients attending at Gondar town health centers, Northwest Ethiopia. *BMC Research Notes*, *11*, 1–8. doi: 10.1186/s13104-018-3789-4

Mhode, M., & Nyamhanga, T. (2016). Experiences and impact of stigma and discrimination among people on antiretroviral therapy in Dar es Salaam: A qualitative perspective. *AIDS Research and Treatment, 2016*(1), 7925052. doi: 10.1155/2016/7925052

Miller, D. R., & Bustamante, C. (2016). Drawing mixed methods procedural diagrams. In A. J. Moeller, J. W. Creswell, & N. Saville (Eds.), *Second language assessment and mixed methods research, Studies in language testing, 43* (pp. 84–118). Cambridge University Press.

Mimiaga, M. J., Reisner, S. L., Reilly, L., Soroudi, N., & Safren, S. A. (2009). Individual interventions. In *HIV prevention* (pp. 203–239). Academic Press. https://www.sciencedirect.com/science/article/abs/pii/B978012374235300008X

Mirabbasi, R., Ahmadi, F., & Jhajharia, D. (2020). Comparison of parametric and non-parametric methods for trend identification in groundwater levels in Sirjan plain aquifer, Iran. *Hydrology Research*, *51*(6), 1455–1477. https://iwaponline.com/hr/article/51/6/1455/77665/Comparison-of-parametric-and-non-parametric

Mkopi, A., Range, N., Lwilla, F., Egwaga, S., Schulze, A., Geubbels, E., & van Leth, F. (2014). Validation of indirect tuberculosis treatment adherence measures in a resource-constrained setting. *The International Journal of Tuberculosis and Lung Disease*, *18*(7), 804–809. https://doi.org/10.5588/ijtld.13.0675

Mobini, S., Allahbakhshian, A., Shabanloei, R., & Sarbakhsh, P. (2023). Illness perception, self-efficacy, and medication adherence in patients with coronary artery disease: A path analysis of conceptual model. *SAGE Open Nursing*, *9*. https://doi.org/10.1177/23779608231171772

Modi, A. C., & Quittner, A. L. (2006). Barriers to treatment adherence for children with cystic fibrosis and asthma: what gets in the way? *Journal of Pediatric Psychology*, *31*(8), 846–858. https://academic.oup.com/jpepsy/article/31/8/846/982994

Mohammed, S., Glennerster, R., & Khan, A. J. (2016). Impact of a daily SMS medication reminder system on tuberculosis treatment outcomes: a randomized controlled trial. *PloS One*, *11*(11), e0162944. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0162944

Mohammed, S., Siddiqi, O., Ali, O., Habib, A., Haqqi, F., Kausar, M., & Khan, A. J. (2012). User engagement with and attitudes towards an interactive SMS reminder system for patients with tuberculosis. *Journal of Telemedicine and Telecare*, *18*(7), 404–408. https://journals.sagepub.com/doi/abs/10.1258/jtt.2012.120311

Mohammedhussein, M., Alenko, A., Tessema, W., & Mamaru, A. (2020). Prevalence and associated factors of depression and anxiety among patients with pulmonary tuberculosis attending treatment at public health facilities in southwest Ethiopia. *Neuropsychiatric Disease and Treatment*, *16*, 1095–1104. https://doi.org/10.2147/NDT.S249431

Mohajan, H. K. (2020). Quantitative research: A successful investigation in natural and social sciences. *Journal of Economic Development, Environment and People*, *9*(4), 50-79. doi:10.26458/jedep.v9i4.679

Molina, Y., Choi, S. W., Cella, D., & Rao, D. (2013). The stigma scale for chronic illnesses 8-item version (SSCI-8): Development, validation and use across neurological conditions. *International Journal of Behavioral Medicine*, *20*, 450–460. https://link.springer.com/article/10.1007/s12529-012-9243-4

Mongkhon, P., Ashcroft, D. M., Scholfield, C. N., & Kongkaew, C. (2018). Hospital admissions associated with medication non-adherence: a systematic review of prospective observational studies. *BMJ Quality & Safety*, *27*(11), 902–914. https://doi.org/10.1136/bmjqs-2017-007453

Moore, D. J., & Posada, C. (2013). HIV and psychiatric co-morbidities: What do we know and what can we do. *Psychology and AIDS Exchange Newsletter*. American Psychological Association, 1.

Morano, J. P., Clauson, K., Zhou, Z., Escobar-Viera, C. G., Lieb, S., Chen, I. K., Kirk, D., Carter, W. M., Ruppal, M., & Cook, R. L. (2019). Attitudes, beliefs, and willingness toward the use of mHealth tools for medication adherence in the Florida mHealth adherence project for people living with HIV (FL-mAPP): Pilot questionnaire study. *JMIR mHealth and uHealth, 7*(7), e12900. https://doi.org/10.2196/12900

Morgan, D. L. (2007). *Focus groups as qualitative research*. Sage.

Morgan, D. L. (2014). Pragmatism as a paradigm for social research. *Qualitative Inquiry, 20*(8), 1045–1053. https://journals.sagepub.com/doi/10.1177/1077800413513733

Morisky, D. E., Ang, A., Krousel-Wood, M., & Ward, H. J. (2008). Predictive validity of a medication adherence measure in an outpatient setting. *The Journal of Clinical Hypertension, 10*(5), 348–354. https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1751-7176.2008.07572.x

Morrissey, E. C., Casey, M., Glynn, L. G., Walsh, J. C., & Molloy, G. J. (2018). Smartphone apps for improving medication adherence in hypertension: Patients' perspectives. *Patient Preference and Adherence*, 813–822. https://doi.org/10.2147/PPA.S145647

Moss-Morris, R., Weinman, J., Petrie, K., Horne, R., Cameron, L., & Buick, D. (2002). The revised illness perception questionnaire (IPQ-R). *Psychology and Health, 17(*1), 1–16. doi: 10.1080/08870440290001494

Moya, E. M., Biswas, A., Chavez Baray, S. M., Martínez, O., & Lomeli, B. (2014). Assessment of stigma associated with tuberculosis in Mexico. *Public Health Action, 4*(4), 226–232. doi: https://doi.org/10.5588/pha.14.0065

Muessig, K. E., LeGrand, S., Horvath, K. J., Bauermeister, J. A., & Hightow-Weidman, L. B. (2017). Recent mobile health interventions to support medication adherence among HIV-positive MSM. *Current Opinion in HIV and AIDS*, *12*(5), 432–441. doi: 10.1097/COH.0000000000000401

Mukora, R., Ahumah, B., Maraba, N., Orrell, C., Jennings, L., Naidoo, P., Fielding, K.L., Velen, K., Charalambous, S., & Chetty-Makkan, C. M. (2023). Acceptability of using the medication monitor and experience of a differentiated care approach for TB treatment adherence among people living with TB in South Africa. *PLoS Global Public Health, 3*(10), e0001885. https://journals.plos.org/globalpublichealth/article?id=10.1371/journal.pgph.0001885

Munro, S., Lewin, S., Swart, T., & Volmink, J. (2007). A review of health behaviour theories: how useful are these for developing interventions to promote long-term medication adherence for TB and HIV/AIDS?. *BMC public health, 7*, 104. https://doi.org/10.1186/1471-2458-7-104

Murray, E. J., Bond, V. A., Marais, B. J., Godfrey-Faussett, P., Ayles, H. M., & Beyers, N. (2013). High levels of vulnerability and anticipated stigma reduce the impetus for tuberculosis diagnosis in Cape Town, South Africa. *Health Policy and Planning*, *28*(4), 410–418. https://academic.oup.com/heapol/article/28/4/410/967327

Musiimenta, A., Tumuhimbise, W., Atukunda, E., Mugaba, A., Linnemayr, S., & Haberer, J. (2023). Digital adherence technologies and mobile money incentives for management of tuberculosis medication among people living with tuberculosis: mixed methods formative study. *JMIR Formative Research*, *7*(1), e45301. doi: 10.2196/45301

Mussie, K. M. (2023). Tuberculosis: A historical and global bioethical perspective. In *Tuberculosis: Integrated studies for a complex disease* (pp. 1033–1046). Springer International. https://link.springer.com/chapter/10.1007/978-3-031-15955-8_49

Myers, M. (2009). *Qualitative research in business and management*. Sage.

Nackers, F., Huerga, H., Espié, E., Aloo, A. O., Bastard, M., Etard, J. F., Sitienei, J., Varaine, F., Chakaya, J., & Bonnet, M. (2012). Adherence to self-administered tuberculosis treatment in a high HIV-prevalence setting: A cross-sectional survey in Homa Bay, Kenya. *PloS One, 7*(3), e32140. https://doi.org/10.1371/journal.pone.0032140

Naderi, S. H., Bestwick, J. P., & Wald, D. S. (2012). Adherence to drugs that prevent cardiovascular disease: meta-analysis on 376,162 patients. *The American Journal of Medicine, 125*(9), 882–887.e1. https://doi.org/10.1016/j.amjmed.2011.12.013

Náfrádi, L., Nakamoto, K., & Schulz, P. J. (2017). Is patient empowerment the key to promote adherence? A systematic review of the relationship between self-efficacy, health locus of control and medication adherence. *PloS One, 12*(10), e0186458. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0186458

Nahid, P., Dorman, S. E., Alipanah, N., Barry, P. M., Brozek, J. L., Cattamanchi, A., Chaisson, L.H., Chaisson, R.E., Daley, C.L., Grzemska, M., Higashi, J.M., Ho, C. S., Hopewell, P. C.,

Keshavjee, S. A., Lienhardt, C., Menzies, R., Merrifield, C., Narita, M., O'Brien, R. … & Vernon, A. (2016). Official American thoracic society/centers for disease control and prevention/infectious diseases society of America clinical practice guidelines: treatment of drug-susceptible tuberculosis. *Clinical Infectious Diseases, 63*(7), e147–e195. https://doi.org/10.1093/cid/ciw376

Naidoo, K., Gengiah, S., Singh, S., Stillo, J., & Padayatchi, N. (2019). Quality of TB care among people living with HIV: Gaps and solutions. *Journal of Clinical Tuberculosis and other Mycobacterial Diseases, 17*, 100122. https://doi.org/10.1016/j.jctube.2019.100122

Naidoo, P. & Mwaba, K. (2010) Helplessness, depression, and social support among people being treated for tuberculosis in South Africa. *Social Behavior and Personality. 38*(10):1323-–1334. http://hdl.handle.net/20.500.11910/4021

Nanji, K. C., Ferris, T. G., Torchiana, D. F., & Meyer, G. S. (2013). Overarching goals: Aa strategy for improving healthcare quality and safety? *BMJ Quality & Safety, 22*(3), 187–193. https://doi.org/10.1136/bmjqs-2012-001082

Ndege, R. C., Okuma, J., Kalinjuma, A. V., Mkumbo, J., Senkoro, E., Fue, G., Samson, L., Mapesi, H., Shabani, S., Glass, T. R., Battegay, M., Paris, D. H., Vanobberghen, F., Weisser, M., & KIULARCO Study Group (2022). Failure to return pillbox is a predictor of being lost to follow-up among people living with HIV on antiretroviral therapy in rural Tanzania. *HIV Medicine, 23*(6), 661–672. https://doi.org/10.1111/hiv.13223

Neuhäuser, M., & Hothorn, L. A. (1999). An exact Cochran–Armitage test for trend when dose–response shapes are a priori unknown. *Computational Statistics & Data Analysis, 30*(4), 403-412. https://doi.org/10.1016/S0167-9473(98)00091-7

Neuman, W.L. (2014). *Social research methods: Qualitative and quantitative approaches.* Allyn & Bacon.

Newton, N. (2010). The use of semi-structured interviews in qualitative research: strengths and weaknesses. *Exploring Qualitative Methods, 1*(1), 1–11. https://www.academia.edu/1561689/The_use_of_semi_structured_interviews_in_qualitative_research_strengths_and_weaknesses

Nezenega, Z.S., Gacho, Y.H. & Tafere, T.E. (2013). Patient satisfaction on tuberculosis treatment service and adherence to treatment in public health facilities of Sidama zone, South Ethiopia. *BMC Health Services Research, 13*, 110. https://doi.org/10.1186/1472-6963-13-110

Nezenega, Z. S., Perimal-Lewis, L., & Maeder, A. J. (2020). Factors influencing patient adherence to tuberculosis treatment in Ethiopia: a literature review. *International Journal of Environmental Research and Public Health, 17*(15), 5626. doi: 10.3390/ijerph17155626

Ngowi, K. M., Minja, L., Boer, I. M. S. D., Aarnoutse, R. E., Masika, L., Sprangers, M. A., Pima, F. M., Mmbaga, B. T., Reiss, P., & Nieuwkerk, P. T. (2022). Predicting viral load suppression by self-reported adherence, pharmacy refill counts and real time medication monitoring among people living with HIV in Tanzania. *AIDS Research and Therapy, 19*(1), 51. https://doi.org/10.1186/s12981-022-00475-y

Ngwatu, B. K., Nsengiyumva, N. P., Oxlade, O., Mappin-Kasirer, B., Nguyen, N. L., Jaramillo, E., Falzon, D., & Schwartzman, K. (2018). The impact of digital health technologies on tuberculosis treatment: a systematic review. *European Respiratory Journal, 51*(1), 1701596. Doi:10.1183/13993003.01596-2017

Ni, Z., Liu, C., Wu, B., Yang, Q., Douglas, C., & Shaw, R. J. (2018). An mHealth intervention to improve medication adherence among patients with coronary heart disease in China: Development of an intervention. *International Journal of Nursing Sciences*, *5*(4), 322–330. https://www.sciencedirect.com/science/article/pii/S2352013218300838

Nieuwlaat, R., Wilczynski, N., Navarro, T., Hobson, N., Jeffery, R., Keepanasseril, A., Agoritsas, T., Mistry, N., Iorio, A., Jack, S., Sivaramalingam, B., & Haynes, R. B. (2014). Interventions for enhancing medication adherence. *Cochrane Database of Systematic Reviews*, (11). doi: 10.1002/14651858.CD000011.pub4

Noble, H., & Smith, J. (2015). Issues of validity and reliability in qualitative research. *Evidence-based Nursing*, *18*(2), 34–35. doi:10.1136/eb-2015-102054

Nour El Din, M., Elhoseeny, T., & Mohsen, A. M. M. A. (2013). Factors affecting defaulting from DOTS therapy under the national programme of tuberculosis control in Alexandria, Egypt. *EMHJ-Eastern Mediterranean Health Journal, 19*(2), 107–113, 2013.

Nwagu, E. N., Abugu, L. I., Yohanna, W., Eze, D. N., Ononuju, A. H., & Obayi, A. N. (2020). Behaviour change communication for control of tuberculosis by healthcare workers in DOTS facilities in Nigeria. *Pan African Medical Journal, 36*(1). doi: 10.11604/pamj.2020.36.306.21640

O'Connor, Y., Andreev, P., & O'Reilly, P. (2020). MHealth and perceived quality of care delivery: A conceptual model and validation. *BMC Medical Informatics and Decision Making, 20,* 1–13. doi: 10.1186/s12911-020-1049-8

O'Donnell, M. R., Wolf, A., Werner, L., Horsburgh, C. R., & Padayatchi, N. (2014). Adherence in the treatment of patients with extensively drug-resistant tuberculosis and HIV in South Africa: a prospective cohort study. *Journal Of Acquired Immune Deficiency Syndromes (1999), 67*(1), 22–29. https://doi.org/10.1097/QAI.0000000000000221

Oates, G. R., Stepanikova, I., Rowe, S. M., Gamble, S., Gutierrez, H. H., & Harris, W. T. (2019). Objective versus self-reported adherence to airway clearance therapy in cystic fibrosis. *Respiratory Care*, *64*(2), 176–181. doi: 10.4187/respcare.06436

Ogedegbe, G., Mancuso, C. A., Allegrante, J. P., & Charlson, M. E. (2003). Development and evaluation of a medication adherence self-efficacy scale in hypertensive African-American patients. *Journal of Clinical Epidemiology, 56*(6), 520–529. https://doi.org/10.1016/s0895-4356(03)00053-2

Ogundele, O. A., Moodley, D., Pillay, A. W., & Seebregts, C. J. (2016). An ontology for factors affecting tuberculosis treatment adherence behavior in sub-Saharan Africa. *Patient Preference and Adherence*, 669–681. https://www.tandfonline.com/doi/full/10.2147/PPA.S96241

Okuboyejo, S., Mbarika, V., & Omoregbe, N. (2018). The effect of self-efficacy and outcome expectation on medication adherence behavior. *Journal of Public Health in Africa*, *9*(3). doi: 10.4081/jphia.2018.826

Ong'ang'o, J. R., Mwachari, C., Kipruto, H., & Karanja, S. (2014). The effects on tuberculosis treatment adherence from utilising community health workers: a comparison of selected rural and urban settings in Kenya. *PloS One, 9*(2), e88937. https://doi.org/10.1371/journal.pone.0088937

Orrell, C., Cohen, K., Leisegang, R., Bangsberg, D. R., Wood, R., & Maartens, G. (2017). Comparison of six methods to estimate adherence in an ART-naïve cohort in a resource-poor setting: which best predicts virological and resistance outcomes? *AIDS Research and Therapy, 14*, 1–11. https://link.springer.com/article/10.1186/s12981-017-0138-y

Osei, E., Kuupiel, D., Vezi, P. N., & Mashamba-Thompson, T. P. (2021). Mapping evidence of mobile health technologies for disease diagnosis and treatment support by health workers in sub-Saharan Africa: Aa scoping review. *BMC Medical Informatics and Decision Making, 21*(1), 11. https://doi.org/10.1186/s12911-020-01381-x

Othman, S., Steen, M., & Fleet, J. (2020). A sequential explanatory mixed methods study design: An example of how to integrate data in a midwifery research project. *Journal of Nursing Education and Practice*, *11*(2), 75–89. https://doi.org/10.5430/jnep.v11n2p75

Pan, Q., Zhang, C., Yao, L., Mai, C., Zhang, J., Zhang, Z., & Hu, J. (2023). Factors influencing medication adherence in elderly patients with hypertension: A single center study in western China. *Patient Preference and Adherence, 17*, 1679–1688. https://doi.org/10.2147/PPA.S418246

Panahi, S., Rathi, N., Hurley, J., Sundrud, J., Lucero, M., & Kamimura, A. (2022). Patient adherence to health care provider recommendations and medication among free clinic patients. *Journal of Patient Experience, 9*, 23743735221077523. https://doi.org/10.1177/23743735221077523

Pansiri, J. (2005). The influence of managers' characteristics and perceptions in strategic alliance practice. *Management Decision, 43*(9), 1097–1113. doi: 10.1108/00251740510626218

Park, L. G., Ng, F., K Shim, J., Elnaggar, A., & Villero, O. (2020). Perceptions and experiences of using mobile technology for medication adherence among older adults with coronary heart disease: A qualitative study. *Digital Health, 6*, 2055207620926844. https://journals.sagepub.com/doi/full/10.1177/2055207620926844

Paschoal, E. P., Santo, C. C. D. E., Gomes, A. M. T., Santos, É. I. D., Oliveira, D. C. D., & Pontes, A. P. M. D. (2014). Adherence to antiretroviral therapy and its representations for people living with HIV/AIDS. *Escola Anna Nery, 18*, 32–40. doi: 10.5935/1414-8145.20140005

Patel, M., Perrin, K., Pritchard, A., Williams, M., Wijesinghe, M., Weatherall, M., & Beasley, R. (2013). Accuracy of patient self-report as a measure of inhaled asthma medication use. *Respirology, 18*(3), 546–552. doi:10.1111/resp.12059.

Patino, C. M., & Ferreira, J. C. (2018). Internal and external validity: can you apply research study results to your patients? *Jornal Brasileiro de Pneumologia*, *44*(03), 183–183. doi: 10.1590/S1806-37562018000000164

Patokorpi, E. (2006). *Role of abductive reasoning in digital interaction*. Åbo Akademi University

Patton, M. Q. (1990). *Qualitative evaluation and research methods*. Sage.

Peltzer, K., Naidoo, P., Matseke, G., Louw, J., Mchunu, G., & Tutshana, B. (2012). Prevalence of psychological distress and associated factors in tuberculosis patients in public primary care clinics in South Africa. *BMC Psychiatry, 12*, 89. https://doi.org/10.1186/1471-244X-12-89

Petit, A., & Cambon, L. (2016). Exploratory study of the implications of research on the use of smart connected devices for prevention: A scoping review. *BMC Public Health, 16*(1), 552. https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-016-3225-4#citeas

Petry, N. M., Rash, C. J., Byrne, S., Ashraf, S., & White, W. B. (2012). Financial reinforcers for improving medication adherence: findings from a meta-analysis. *The American Journal of Medicine, 125*(9), 888–896. https://doi.org/10.1016/j.amjmed.2012.01.003

Phillips, T., Brittain, K., Mellins, C. A., Zerbe, A., Remien, R. H., Abrams, E. J., Myer, L., & Wilson, I. B. (2017). A self-reported adherence measure to screen for elevated HIV viral load in pregnant and postpartum women on antiretroviral therapy. *AIDS and Behavior*, *21*, 450–461. doi: 10.1007/s10461-016-1448-0

Pop-Eleches, C., Thirumurthy, H., Habyarimana, J. P., Zivin, J. G., Goldstein, M. P., de Walque, D., MacKeen, L., Haberer, J., Kimaiyo, S., Sidle, J., Ngare, D., & Bangsberg, D. R. (2011). Mobile phone technologies improve adherence to antiretroviral treatment in a resource-limited setting: Aa randomized controlled trial of text message reminders. *AIDS (London, England), 25*(6), 825–834. https://doi.org/10.1097/QAD.0b013e32834380c1

Powell, T. C. (2001). Competitive advantage: logical and philosophical considerations. *Strategic Management Journal, 22*(9), 875–888. https://onlinelibrary.wiley.com/doi/pdf/10.1002/smj.173

Pradipta, I. S., Houtsma, D., van Boven, J. F., Alffenaar, J. W. C., & Hak, E. (2020). Interventions to improve medication adherence in tuberculosis patients: a systematic review of randomized controlled studies. *NPJ Primary Care Respiratory Medicine*, *30*(1), 21. https://www.nature.com/articles/s41533-020-0179-x

Rachman, S. (1980). Emotional processing. *Behaviour Research and Therapy*, *18*(1), 51–60. doi: 10.1016/0005-7967(80)90069-8

Ramli, A., Ahmad, N. S., & Paraidathathu, T. (2012). Medication adherence among hypertensive patients of primary health clinics in Malaysia. *Patient Preference and Adherence*, 6132622. doi: 10.2147/PPA.S34704

Rau, H., & Williams, P. (2013). Illness cognitions and perceptions. *Encyclopedia of behavioral medicine.* Springer.

Raykov, T., & Marcoulides, G. A. (2011). *Introduction to psychometric theory*. Routledge.

Read, S., Morgan, J., Gillespie, D., Nollett, C., Weiss, M., Allen, D., Anderson, P., & Waterman, H. (2020). Chronic conditions and behavioural change approaches to medication adherence: rethinking clinical guidance and recommendations. *Patient Preference and Adherence*, 581–586. https://www.tandfonline.com/doi/pdf/10.2147/PPA.S239916

Redmond, B. F. (2010). Self-efficacy theory: Do I think that I can succeed in my work. *Work attitudes and motivation*.

Reeves, T., & Hedberg, J. G. (2003). *Interactive learning systems evaluation*. Educational Technology Publications.

Reid, R., & Dale, S. K. (2022). Moderating effects of social support on the relationship between substance use disorders and HIV viral load and medication adherence among Black women living with HIV in the United States. *AIDS Care, 34*(10), 1219–1228. https://doi.org/10.1080/09540121.2021.2001415

Revelle, W., & Zinbarg, R. E. (2009). Coefficients alpha, beta, omega, and the glb: Comments on Sijtsma. *Psychometrika*, *74*, 145–154. doi:10.1007/s11336-008-9102-z

Robson, C. (2011). *Real world research: A resource for social-scientists and practitioner-researchers*. Blackwell.

Rorty, R. (1989). The contingency of a liberal community. *Contingency, irony, and solidarity*, (pp. 44-69). Cambridge University Press.

Rosenstock, I. M. (1960). What research in motivation suggests for public health. *American Journal of Public Health and the Nation's Health*, *50*(3_Pt_1), 295-302. doi: 10.2105/ajph.50.3_pt_1.295

Rosenstock, I. M. (1974). Historical origins of the health belief model. *Health Education Monographs*, *2*(4), 328–335. https://journals.sagepub.com/doi/abs/10.1177/109019817400200403

Rosli, N. A., Mazapuspavina, M. Y., Ismail, Z., & Elkudssiah Ismail, N. (2022). Relationship of self-efficacy in medication understanding with quality of life among elderly with type 2 diabetes mellitus on polypharmacy in Malaysia. *International Journal of Environmental Research and Public Health*, *19*(5), 3031. doi: 10.3390/ijerph19053031

Ross, E., & Deverell, A. (2004). *Psychosocial approaches to health, illness and disability: A reader for health care professionals*. Van Schaik.

Ruru, Y., Matasik, M., Oktavian, A., Senyorita, R., Mirino, Y., Tarigan, L. H., van der Werf, M. J., Tiemersma, E., & Alisjahbana, B. (2018). Factors associated with non-adherence during

tuberculosis treatment among patients treated with DOTS strategy in Jayapura, Papua Province, Indonesia. *Global Health Action, 11*(1), 1510592. https://doi.org/10.1080/16549716.2018.1510592

Sabaté, E. (Ed.). (2003). *Adherence to long-term therapies: Evidence for action.* World Health Organization.

Saberi, P., & Johnson, M. O. (2011). Technology-based self-care methods of improving antiretroviral adherence: a systematic review. *PloS One, 6*(11), e27533. https://doi.org/10.1371/journal.pone.0027533

Sabin, L. L., DeSilva, M. B., Gill, C. J., Zhong, L., Vian, T., Xie, W., Cheng, F., Xu, K., Lan, G., Haberer, J.E., & Bangsberg, D.R. (2015). Improving adherence to antiretroviral therapy with triggered real time text message reminders: the China through technology study (CATS). *Journal of Acquired Immune Deficiency Syndromes (1999), 69*(5), 551. doi: 10.1097/QAI.0000000000000651

Sadeghi, R., Masoudi, M. R., Patelarou, A., & Khanjani, N. (2022). Predictive factors for the care and control of hypertension based on the health belief model among hypertensive patients during the COVID-19 epidemic in Sirjan, Iran. *Current Hypertension Reviews, 18*(1), 78–84. https://doi.org/10.2174/1573402117666210603115309

Sahile, Z., Yared, A., & Kaba, M. (2018). Patients' experiences and perceptions on associates of TB treatment adherence: a qualitative study on DOTS service in public health centers in Addis Ababa, Ethiopia. *BMC Public Health, 18*(1), 462. doi: 10.1186/s12889-018-5404-y

Sales, B. D., & Folkman, S. (Eds.). (2000). *Ethics in research with human participants*. American Psychological Association.

Sallis, J. F., Owen, N., & Fisher, E. B. (2008). Ecological models of health behavior. In K. Glanz, B. K. Rimer, & K. Viswanath (Eds.), Health behavior and health education: Theory, research, and practice (pp. 465-486). San Francisco, CA: Jossey-Bass.

Sangeda, R. Z., Mosha, F., Prosperi, M., Aboud, S., Vercauteren, J., Camacho, R. J., Lyamuya, E.F., van Wijngaerden, E., & Vandamme, A. M. (2014). Pharmacy refill adherence outperforms self-reported methods in predicting HIV therapy outcome in resource-limited settings. *BMC Public Health, 14*, 1–11. https://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-14-1035

Santos, J. L. G. D., Erdmann, A. L., Meirelles, B. H. S., Lanzoni, G. M. D. M., Cunha, V. P. D., & Ross, R. (2017). Integrating quantitative and qualitative data in mixed methods research. *Texto & Contexto-Enfermagem, 26,* e1590016. doi:10.1590/01040707201700159001 6

Saranjam, F., Afrasiabifar, A., Alamdari, A., & Hosseini, N. (2023). Effect of Leventhal's self-regulatory intervention on the hypertensive patients' illness perception and lifestyle: a randomized controlled trial. *BMC Cardiovascular Disorders, 23*(1), 50. https://doi.org/10.1186/s12872-023-03049-6

Sarkar, S., Balhara, Y. P. S., Kumar, S., Saini, V., Kamran, A., Patil, V., Singh, S., & Gyawali, S. (2019). Internalized stigma among patients with substance use disorders at a tertiary care center in India. *Journal of Ethnicity in Substance Abuse, 18*(3), 345–358. https://doi.org/10.1080/15332640.2017.1357158

Sarradon-Eck, A., Bouchez, T., Auroy, L., Schuers, M., & Darmon, D. (2021). Attitudes of general practitioners toward prescription of mobile health apps: Qualitative study. *JMIR mHealth and uHealth, 9*(3), e21795. doi: 10.2196/21795

Schmidt C. W. (2008). Linking TB and the environment: an overlooked mitigation strategy. *Environmental Health Perspectives, 116*(11), A478–A485. https://doi.org/10.1289/ehp.116-a478

Schunk, D. H. (2013). Social cognitive theory and self-regulated learning. In *Self-regulated learning and academic achievement* (pp. 119-144). Routledge. https://www.taylorfrancis.com/chapters/edit/10.4324/9781410601032-4/social-cognitive-theory-self-regulated-learning-dale-schunk

Schwandt, T. A. (2001). Dictionary of qualitative inquiry. In *Dictionary of qualitative inquiry* (pp. xxxiv-281). Sage.

Shadish, W. R., Cook, T.D., & Campbell, D.T. (2002). *Experimental and quasi-experimental designs for generalized causal inference.* Houghton Mifflin.

Shen, Z., Shi, S., Ding, S., & Zhong, Z. (2020). Mediating effect of self-efficacy on the relationship between medication literacy and medication adherence among patients with hypertension. *Frontiers in Pharmacology, 11*, 569092. doi: 10.3389/fphar.2020.569092

Sinkou, H., Hurevich, H., Rusovich, V., Zhylevich, L., Falzon, D., de Colombani, P., Dadu, A., Dara, M., Story, A., & Skrahina, A. (2017). Video-observed treatment for tuberculosis patients in Belarus: findings from the first programmatic experience. *European Respiratory Journal, 49*(3), 1602049. doi**:** 10.1183/13993003.02049-2016

Skinner, B. F. (1974). The experimental analysis of behavior. In W. G Van der Kloot, C. Walcott & B. Dane (Eds.). *Readings in behavior*, 35. Ardent Media.

Soobratty, M. R., Whitfield, R., Subramaniam, K., Grove, G., Carver, A., O'Donovan, G. V., Wu, H. H., Lee, O. Y., Swaminathan, R., Cope, G. F., & Milburn, H. J. (2014). Point-of-care urine test for assessing adherence to isoniazid treatment for tuberculosis. *The European Respiratory Journal*, *43*(5), 1519–1522. https://doi.org/10.1183/09031936.00132613

South African Medical Research Council (2023). Media press release: Committed to the reduction of fatalities resulting from Tuberculosis. https://www.samrc.ac.za/press-releases/committed-reduction-fatalities-resulting-tuberculosis

Stagg, H. R., Lewis, J. J., Liu, X., Huan, S., Jiang, S., Chin, D. P., & Fielding, K. L. (2020). Temporal factors and missed doses of tuberculosis treatment. A causal associations approach to analyses of digital adherence data. *Annals of the American Thoracic Society*, *17*(4), 438–449. https://www.atsjournals.org/doi/full/10.1513/AnnalsATS.201905-394OC

Stawarz, K., Cox, A., & Blandford, A. (2016). Understanding the role of contextual cues in supporting the formation of medication-taking habits. In *Front Public Health (Conference Abstract: 2nd Behaviour Change Conference: Digital Health and Wellbeing)* (Vol. 10). https://www.frontiersin.org/10.3389/conf.FPUBH.2016.01.00066/event_abstract

Stich, S. P. (1990). *The fragmentation of reason: Preface to a pragmatic theory of cognitive evaluation*. The MIT Press.

Stokols D. (1992). Establishing and maintaining healthy environments. Toward a social ecology of health promotion. The American psychologist, 47(1), 6–22. https://doi.org/10.1037//0003-066x.47.1.6

Stokols, D. (1996). Translating social ecological theory into guidelines for community health promotion. *American Journal of Health Promotion*, *10*(4), 282–298. https://journals.sagepub.com/doi/abs/10.4278/0890-1171-10.4.282

Stokols, D., Pelletier, K. R., & Fielding, J. E. (1996). The ecology of work and health: research and policy directions for the promotion of employee health. Health education quarterly, 23(2), 137–158. https://doi.org/10.1177/109019819602300202

Stop TB Partnership. *Wave 6 digital adherence technology projects* [Internet]. http://stoptb.org/global/awards/tbreach/wave6DAT.asp (Accessed on 23 June 2021).

Stoumpos, A. I., Kitsios, F., & Talias, M. A. (2023). Digital transformation in healthcare: technology acceptance and its applications. *International Journal of Environmental Research and Public Health*, *20*(4), 3407. doi: 10.3390/ijerph20043407

Subbaraman, R., de Mondesert, L., Musiimenta, A., Pai, M., Mayer, K. H., Thomas, B. E., & Haberer, J. (2018). Digital adherence technologies for the management of tuberculosis therapy: mapping the landscape and research priorities. *BMJ Global Health, 3*(5). doi:10.1136/ bmjgh-2018-001018

Subbaraman, R., Thomas, B. E., Kumar, J. V., Thiruvengadam, K., Khandewale, A., Kokila, S., Lubeck-Schricker, M., Ranjith Kumar, M., Gaurkhede, G.R., Walgude, A.S, Hephzibah Mercy, J., Khumbar, J. D., Eliasziw, M., Mayer, K. H., & Haberer, J. E. (2021, June). Understanding nonadherence to tuberculosis medications in India using urine drug metabolite testing: a cohort study. In *Open Forum Infectious Diseases*, 8(6), ofab190). Oxford University Press. https://academic.oup.com/ofid/article/8/6/ofab190/6267282

Subu, M. A., Wati, D. F., Netrida, N., Priscilla, V., Dias, J. M., Abraham, M. S., Slewa-Youna, S., & Al-Yateem, N. (2021). Types of stigma experienced by patients with mental illness and mental health nurses in Indonesia: a qualitative content analysis. *International Journal of Mental Health Systems, 15*, 1–12. https://doi.org/10.1186/s13033-021-00502-x

Suls, J., & Rothman, A. (2004). Evolution of the biopsychosocial model: prospects and challenges for health psychology. *Health Psychology*, *23*(2), 119. https://psycnet.apa.org/record/2004-11615-002

Suryaningrum, C. (2018, February). The correlation of self-construal, self-efficacy, and emotional regulation strategy as cultural factors with social anxiety: Preliminary study. In *3rd ASEAN Conference on Psychology, Counselling, and Humanities (ACPCH 2017)* (pp. 182-–187). Atlantis Press. doi:10.2991/acpch-17.2018.36

Tan, F. C. J. H., Oka, P., Dambha-Miller, H., & Tan, N. C. (2021). The association between self-efficacy and self-care in essential hypertension: a systematic review. *BMC Family Practice, 22*, 1–12. https://bmcprimcare.biomedcentral.com/articles/10.1186/s12875-021-01391-2

Tanimura, T., Jaramillo, E., Weil, D., Raviglione, M., & Lönnroth, K. (2014). Financial burden for tuberculosis patients in low- and middle-income countries: a systematic review. *The European Respiratory Journal, 43*(6), 1763–1775. https://doi.org/10.1183/09031936.00193413

Tashakkori, A., & Teddlie, C. (1998). *Mixed methodology: Combining qualitative and quantitative approaches*. Sage.

Taukeni, S. G. (2019). Introductory chapter: Bio-psychosocial model of health. In *Psychology of health – Biopsychosocial approach.* Intech open. DOI:10.5772/intechopen.85024

Taukeni, S. G. (2020). *Psychology and psychiatry: Open access*. https://www.researchgate.net/publication/344844447_Biopsychosocial_Model_of_Health

TB DIAH Project (2024). https://hub.tbdiah.org/dashboards/countries/south-africa

Teddlie, C., & Tashakkori, A. (2003). Major issues and controversies in the use of mixed methods in the social and behavioral sciences. In *Handbook of mixed methods in social and behavioral research*. Sage.

Thamineni, R., Peraman, R., Chenniah, J., Meka, G., Munagala, A. K., Mahalingam, V. T., & Ganesan, R. M. (2022). Level of adherence to anti-tubercular treatment among drug-sensitive tuberculosis patients on a newly introduced daily dose regimen in South India: A cross-sectional study. *Tropical Medicine & International Health, 27*(11), 1013–1023. doi: 10.1111/tmi.13824

Thekkur, P., Kumar, A. M., Chinnakali, P., Selvaraju, S., Bairy, R., Singh, A. R., Nirgude, A., Selvaraj, K., Venugopal, V., & Shastri, S. (2019). Outcomes and implementation challenges of using daily treatment regimens with an innovative adherence support tool among HIV-infected tuberculosis patients in Karnataka, India: a mixed-methods study. *Global Health Action, 12*(1), 1568826. https://www.tandfonline.com/doi/full/10.1080/16549716.2019.1568826

Thomas, B. E., Kumar, J. V., Chiranjeevi, M., Shah, D., Khandewale, A., Thiruvengadam, K., Haberer, J.E., Mayer, K.H., & Subbaraman, R. (2020b). Evaluation of the accuracy of 99DOTS, a novel cell phone-based strategy for monitoring adherence to tuberculosis medications: comparison of Digital adherence data with urine isoniazid testing. *Clinical Infectious Diseases, 71*(9), e513-e516. https://academic.oup.com/cid/article/71/9/e513/5812993

Thomas, B. E., Kumar, J. V., Onongaya, C., Bhatt, S. N., Galivanche, A., Periyasamy, M., Chiranjeevi, M., Khandewale, A.S., Ramachandran, G., Shah, D., Haberer, J.E., Mayer, K. H., & Subbaraman, R. (2020a). Explaining differences in the acceptability of 99DOTS, a cell phone–based strategy for monitoring adherence to tuberculosis medications: qualitative study of patients and health care providers. *JMIR mHealth and uHealth, 8*(7), e16634. doi: 10.2196/16634

Thomas, B. E., Kumar, J. V., Periyasamy, M., Khandewale, A. S., Hephzibah Mercy, J., Raj, E. M., Kokila, S., Walgude, A.S., Gaurkhede, G.R., Kumbhar, J.D., Ovung, S., Pail, M., Rajkumar, B.S., & Subbaraman, R. (2021). Acceptability of the medication event reminder monitor for promoting adherence to multidrug-resistant tuberculosis therapy in two Indian cities:

qualitative study of patients and health care providers. *Journal of Medical Internet Research*, *23*(6), e23294. doi: 10.2196/23294

Tibble, H., Flook, M., Sheikh, A., Tsanas, A., Horne, R., Vrijens, B., De Geest, S., & Stagg, H. R. (2021). Measuring and reporting treatment adherence: What can we learn by comparing two respiratory conditions? *British Journal of Clinical Pharmacology, 87*(3), 825–836. https://doi.org/10.1111/bcp.14458

Ting, N. C. H., El-Turk, N., Chou, M. S. H., & Dobler, C. C. (2020). Patient-perceived treatment burden of tuberculosis treatment. *PloS One, 15*(10), e0241124. https://doi.org/10.1371/journal.pone.0241124

Tola, H. H., Garmaroudi, G., Shojaeizadeh, D., Tol, A., Yekaninejad, M. S., Ejeta, L. T., Kebede, A., & Kassa, D. (2017). The effect of psychosocial factors and patients' perception of tuberculosis treatment non-adherence in Addis Ababa, Ethiopia. *Ethiopian Journal of Health Sciences*, *27*(5), 447–448. doi: 10.4314/ejhs.v27i5.2

Tola, H. H., Shojaeizadeh, D., Garmaroudi, G., Tol, A., Yekaninejad, M. S., Ejeta, L. T., Kebede, A., Karimi, M., & Kassa, D. (2015). Psychological distress and its effect on tuberculosis treatment outcomes in Ethiopia. *Global Health Action, 8*, 29019. https://doi.org/10.3402/gha.v8.29019

Tomlinson, M., Rotheram-Borus, M. J., Swartz, L., & Tsai, A. C. (2013). Scaling up mHealth: where is the evidence? *PLoS Medicine, 10*(2), e1001382. https://doi.org/10.1371/journal.pmed.1001382

Townsend, J. T., Hu, G. G., & Evans, R. J. (1984). Modeling feature perception in brief displays with evidence for positive interdependencies. *Perception & Psychophysics*, *36*, 35–49. https://link.springer.com/article/10.3758/BF03206352

Unni, E., & Bae, S. (2022). Exploring a new theoretical model to explain the behavior of medication adherence. *Pharmacy*, *10*(2), 43. doi: 10.3390/pharmacy10020043

Usitalo, A., Leister, E., Tassiopoulos, K., Allison, S., Malee, K., Paul, M. E., Smith, R., van Dyke, R.B., Seage III, G.R., & Mellins, C. A. (2014). Relationship between viral load and self-report measures of medication adherence among youth with perinatal HIV infection. *AIDS Care*, *26*(1), 107–115. https://doi.org/10.1080/09540121.2013.802280

Valencia, S., León, M., Losada, I., Sequera, V. G., Fernández Quevedo, M., & García-Basteiro, A. L. (2017). How do we measure adherence to anti-tuberculosis treatment? *Expert Review of Anti-infective Therapy*, *15*(2), 157–165. https://doi.org/10.1080/14787210.2017.1264270

van Broekhoven, M. E. C. L., de Rooij, B. H., Pijnenborg, J. M. A., Vos, M. C., Boll, D., Kruitwagen, R. F. P. M., van de Poll-Franse, L. V., & Ezendam, N. P. M. (2017). Illness perceptions and changes in lifestyle following a gynecological cancer diagnosis: A longitudinal analysis. *Gynecologic Oncology, 145*(2), 310–318. https://doi.org/10.1016/j.ygyno.2017.02.037

van den Boogaard, J., Lyimo, R. A., Boeree, M. J., Kibiki, G. S., & Aarnoutse, R. E. (2011). Electronic monitoring of treatment adherence and validation of alternative adherence measures in tuberculosis patients: a pilot study. *Bulletin of the World Health Organization, 89*(9), 632–639. https://doi.org/10.2471/BLT.11.086462

van der Bijl, J. J., & Shortridge-Baggett, L. M. (2002). The theory and measurement of the self-efficacy construct. *Self-efficacy in Nursing: Research and Measurement Perspectives, 15*(3), 189–220.

van Griethuijsen, R. A., van Eijck, M. W., Haste, H., Den Brok, P. J., Skinner, N. C., Mansour, N., Savran Gencer, A., & BouJaoude, S. (2015). Global patterns in students' views of science and interest in science. *Research in Science Education, 45*, 581–603. doi:10.1007/s11165-014-9438-6

Vanleeuw, L., Zembe-Mkabile, W., & Atkins, S. (2022). "I'm suffering for food": Food insecurity and access to social protection for TB patients and their households in Cape Town, South Africa. *PloS One, 17*(4), e0266356. https://doi.org/10.1371/journal.pone.0266356

Veggi, A. B., Lopes, C. S., Faerstein, E., & Sichieri, R. (2004). Body mass index, body weight perception and common mental disorders among university employees in Rio de Janeiro. *Brazilian Journal of Psychiatry, 26,* 242–247. https://www.scielo.br/j/rbp/a/qNJ5bnGNJFg8bzPcJszRVvq/?lang=enchrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.scielo.br/j/rbp/a/qNJ5bnGNJFg8bzPcJszRVvq/?format=pdf&lang=en

Venkatachalam, J., Abrahm, S. B., Singh, Z., Stalin, P., & Sathya, G. R. (2015). Determinants of patient's adherence to hypertension medications in a rural population of Kancheepuram District in Tamil Nadu, South India. *Indian Journal of Community Medicine, 40*(1), 33–37. doi: 10.4103/0970-0218.149267

Vervloet, M., van Dijk, L., de Bakker, D., Souverein, P., Santen-Reestman, J., van Vlijmen, B., van Aarle, M.C.W., van Der Hoek, L.S., & Bouvy, M. (2014). Short-and long-term effects of real-time medication monitoring with short message service (SMS) reminders for missed

doses on the refill adherence of people with Type 2 diabetes: evidence from a randomized controlled trial. *Diabetic Medicine, 31*(7), 821–828. https://doi.org/10.1111/dme.12439

Vervloet, M., Linn, A. J., van Weert, J. C., De Bakker, D. H., Bouvy, M. L., & Van Dijk, L. (2012). The effectiveness of interventions using electronic reminders to improve adherence to chronic medication: a systematic review of the literature. *Journal of the American Medical Informatics Association, 19*(5), 696–704. https://doi.org/10.1136/amiajnl-2011-000748

Vik, S. A., Maxwell, C. J., & Hogan, D. B. (2004). Measurement, correlates, and health outcomes of medication adherence among seniors. *Annals of Pharmacotherapy*, *38*(2), 303–312. https://journals.sagepub.com/doi/full/10.1345/aph.1D252

Vinson, R. C. K. T., Baruiz, C. P., & Pelegrino, M. (2015). Biopsychosocial factors affecting the treatment outcomes of pulmonary tuberculosis among patients enrolled in TB DOTS clinics. *SPMC Journal of Health Care Services*, *1*(1). https://www.new.spmcpapers.com/index.php/jhcs/article/view/32

Vo, V., Auroy, L., & Sarradon-Eck, A. (2019). Patients' Perceptions of mHealth Apps: Meta-Ethnographic Review of Qualitative Studies. *JMIR mHealth and uHealth, 7*(7), e13817. https://mhealth.jmir.org/2019/7/e13817/

Vogel, D. L., Bitman, R. L., Hammer, J. H., & Wade, N. G. (2013). Is stigma internalized? The longitudinal impact of public stigma on self-stigma. *Journal of Counseling Psychology, 60*(2), 311–316. https://doi.org/10.1037/a0031889

Vogel, D. L., Strass, H. A., Heath, P. J., Al-Darmaki, F. R., Armstrong, P. I., Baptista, M. N., Brenner, R. E., Gonçalves, M., Lannin, D. G., Liao, H.-Y., Mackenzie, C. S., Mak, W. W. S., Rubin, M., Topkaya, N., Wade, N. G., Wang, Y.-F., & Zlati, A. (2017). Stigma of seeking psychological services: Examining college students across ten countries/regions. *The Counseling Psychologist, 45*(2), 170–192. https://doi.org/10.1177/0011000016671411

Vogel, D. L., Wade, N., & Haake, S. (2006). Measuring the self-stigma associated with seeking psychological help. *Journal of Counseling Psychology, 53*(3), 325–337. doi:10.1037/0022-0167.53.3.325

Vogel, D. L., Wade, N., & Hackler, A. (2007). Perceived public stigma and the willingness to seek counseling: The mediating roles of self-stigma and attitudes towards counseling. *Journal of Counseling Psychology*, *54*(1), 40–50. doi:10.1037/0022-0167.54.1.40

Wagner, C., Kawulich, B., & Garner, M. (2012). *Doing social research: A global context*. McGraw-Hill.

Wagner, G., & Miller, L. G. (2004). Is the influence of social desirability on patients' self-reported adherence overrated?. *JAIDS Journal of Acquired Immune Deficiency Syndromes*, *35*(2), 203–204. doi: 10.1097/00126334-200402010-00018

Wald, D. S., Butt, S., & Bestwick, J. P. (2015). One-way versus two-way text messaging on improving medication adherence: meta-analysis of randomized trials. *The American Journal of Medicine, 128*(10), 1139-e1. https://doi.org/10.1016/j.amjmed.2015.05.035

Wang, N., Shewade, H. D., Thekkur, P., Huang, F., Yuan, Y., Wang, X., Wang, X., Sun, M., & Zhang, H. (2020). Electronic medication monito for people with tuberculosis: implementation experience from thirty counties in China. *PLoS One*, *15*(4), e0232337. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0232337

Wang, T., Tan, J. Y., Xiao, L. D., & Deng, R. (2017). Effectiveness of disease-specific self-management education on health outcomes in patients with chronic obstructive pulmonary disease: an updated systematic review and meta-analysis. *Patient Education and Counseling*, *100*(8), 1432–1446. https://www.sciencedirect.com/science/article/abs/pii/S0738399117301179

Wang, N., Zhang, H., Zhou, Y., Jiang, H., Dai, B., Sun, M., Li, Y., Kinter, A., & Huang, F. (2019). Using electronic medication monitoring to guide differential management of tuberculosis patients at the community level in China. *BMC Infectious Diseases*, *19*, 1–9. https://link.springer.com/article/10.1186/s12879-019-4521-2

Ware, N. C., Pisarski, E. E., Tam, M., Wyatt, M. A., Atukunda, E., Musiimenta, A., Bangsberg, D. R., & Haberer, J. E. (2016). The meanings in the messages: How SMS reminders and real-time adherence monitoring improve antiretroviral therapy adherence in rural Uganda. *AIDS (London, England)*, *30*(8), 1287–1294. https://doi.org/10.1097/QAD.0000000000001035

Washburn, L. (2020). *Understanding the health belief model.* University of Tennessee.

Wei, L., Champman, S., Li, X., Li, X., Li, S., Chen, R., Bo, N., Chater, A., & Horne, R. (2017). Beliefs about medicines and non-adherence in patients with stroke, diabetes mellitus and rheumatoid arthritis: a cross-sectional study in China. *BMJ Open*, *7*(10), e017293. doi:10.1136/ bmjopen-2017-017293

Wells, K. J., Pan, T. M., Vázquez-Otero, C., Ung, D., Ustjanauskas, A. E., Muñoz, D., Laronga, C., Roetzheim, R.G., Goldenstein, M., Carrizosa, C., Nuhaily, S., Johnson, K., Norton, M., Sims, E., & Quinn, G. P. (2016). Barriers and facilitators to endocrine therapy adherence among underserved hormone-receptor-positive breast cancer survivors: a qualitative study.

Supportive Care in Cancer, *24*, 4123–4130. https://link.springer.com/article/10.1007/s00520-016-3229-8

Western Cape Government (2023). https://www.westerncape.gov.za/site-page/provincial-tb-dashboard

Wicks, A. C., & Freeman, R. E. (1998). Organization studies and the new pragmatism: Positivism, anti-positivism, and the search for ethics. *Organization Science*, *9*(2), 123–140. https://www.jstor.org/stable/2640349

William, F. K. A. (2024). Mastering validity and reliability in academic research: Meaning and significance. *International Journal of Research Publications*, *144*(1), 287–292. doi: 10.47119/IJRP1001441320246160

Williams, J. D., & Takaku, S. (2011). Help seeking, self-efficacy, and writing performance among college students. *Journal of Writing Research*, *3*(1), 1–18. https://jowr.org/index.php/jowr/article/view/727

Willig, C. (2008). *Introducing qualitative research methods in psychology*. McGraw Hill.

Willig, C. (2013). *Sage handbook of qualitative research in psychology*. Sage.

Willig, C. (2014). Interpretation and analysis. *The Sage handbook of qualitative data analysis*. Sage.

Wilson, I. B., Fowler, F. J., Cosenza, C. A., Michaud, J., Bentkover, J., Rana, A., Kogelman, L., & Rogers, W. H. (2014). Cognitive and field testing of a new set of medication adherence self-report items for HIV care. *AIDS and Behavior*, *18*, 2349–2358. doi: 10.1007/s10461-013-0610-1

Wilson, I. B., Lee, Y., Michaud, J., Fowler Jr, F. J., & Rogers, W. H. (2016). Validation of a new three-item self-report measure for medication adherence. *AIDS and Behavior*, *20*(11), 2700–2708. doi: 10.1007/s10461-016-1406-x.

Wilson, T. E., Hennessy, E. A., Falzon, L., Boyd, R., Kronish, I. M., & Birk, J. L. (2020). Effectiveness of interventions targeting self-regulation to improve adherence to chronic disease medications: A meta-review of meta-analyses. *Health Psychology Review*, *14*(1), 66–85. https://www.tandfonline.com/doi/full/10.1080/17437199.2019.1706615

Wisepill Technologies (2023, July 18). Wisepill: medication adherence solutions through innovation. https://www.wisepill.com/

Woimo, T. T., Yimer, W. K., Bati, T., & Gesesew, H. A. (2017). The prevalence and factors associated for anti-tuberculosis treatment non-adherence among pulmonary tuberculosis

patients in public health care facilities in South Ethiopia: A cross-sectional study. *BMC Public Health, 17*(1), 269. https://doi.org/10.1186/s12889-017-4188-9

Woode, E., Boakye-Gyasi, E., Obirikorang, Y., Adu, E. A., Obirikorang, C., Acheampong, E., & Odame-Anto, E. (2022). Predictors of medication nonadherence among hypertensive clients in a Ghanaian population: Application of the Hill-Bone and Perceived Barriers to Treatment Compliance Scale. *Health Science Reports, 5*(3), e584. doi: 10.1002/hsr2.584

Woods, L. S., Duff, J., Roehrer, E., Walker, K., & Cummings, E. (2019). Patients' experiences of using a consumer mHealth app for self-management of heart failure: Mixed-methods study. *JMIR Human Factors*, *6*(2), e13009. https://humanfactors.jmir.org/2019/2/e13009/

World Health Organization. (2003). *Adherence to long-term therapies: Evidence for action*. World Health Organization. https://iris.who.int/handle/10665/42682

World Health Organization (WHO) (2007) *Everybody's business. Strengthening health systems to improve health outcomes: WHO's Aa framework for action*.

World Health Organization. (WHO). (2008). *International health regulations 2005.* World Health Organization.

World Health Organization. (WHO).(2010). *The global plan to stop TB 2011-2015: Transforming the fight towards elimination of tuberculosis*. World Health Organization.

Word Health Organization. (WHO) (2017). *Guidelines for treatment of drug-susceptible tuberculosis and patient care*. http://www.who.int/tb/publications/2017/dstb_guidance_2017/en/

World Health Organization. (WHO) (2018). *Global tuberculosis report 2018*: World Health Organization. https://www.who.int/tb/publications/global_report/en/

World Health Organization. (2019). *Global tuberculosis report 2019.* World Health Organization. https://www.who.int/publications/i/item/9789241565714

World Health Organization. (2020). *Global tuberculosis report 2020.* World Health Organization. https://www.who.int/publications/i/item/9789240013131

World Health Organization. (2021). *Global tuberculosis report 2020*. World Health Organization. https://www.who.int/publications/i/item/9789240037021

World Health Organization. (2022). *Global tuberculosis report 2021: Supplementary material*. World Health Organization. https://www.who.int/publications/i/item/9789240037021

World Health Organization. (2022). *Global tuberculosis report 2020*. World Health Organization. https://iris.who.int/bitstream/handle/10665/363752/9789240061729-eng.pdf

World Health Organization. (2023). *Global tuberculosis report 2020*. World Health Organization. https://www.who.int/teams/global-tuberculosis-programme/tb-reports/global-tuberculosis-report-2023

World Health Organization, South Africa. (2024). *Intensifying efforts to end TB.* https://www.afro.who.int/countries/south-africa/news/south-africa-intensifying-efforts-end-tb

Xiong, S., Berkhouse, H., Schooler, M., Pu, W., Sun, A., Gong, E., & Yan, L. L. (2018). Effectiveness of mHealth interventions in improving medication adherence among people with hypertension: a systematic review. *Current Hypertension Reports, 20*, 1–15. https://link.springer.com/article/10.1007/s11906-018-0886-7

Xu, Z., Huang, F., Koesters, M., & Ruesch, N. (2017). Challenging mental health-related stigma in China: Systematic review and meta-analysis. II. Interventions among people with mental illness. *Psychiatry Research, 255*, 457–464. https://doi.org/10.1016/j.psychres.2017.05.002

Yaraghchi, A., Rezaei, O., Mandegar, M. H., & Bagherian, R. (2012). The relationship between illness perception and quality of life in Iranian patients with coronary artery bypass graft. *Procedia-Social and Behavioral Sciences, 46*, 3329–3334. https://www.sciencedirect.com/science/article/pii/S1877042812017971

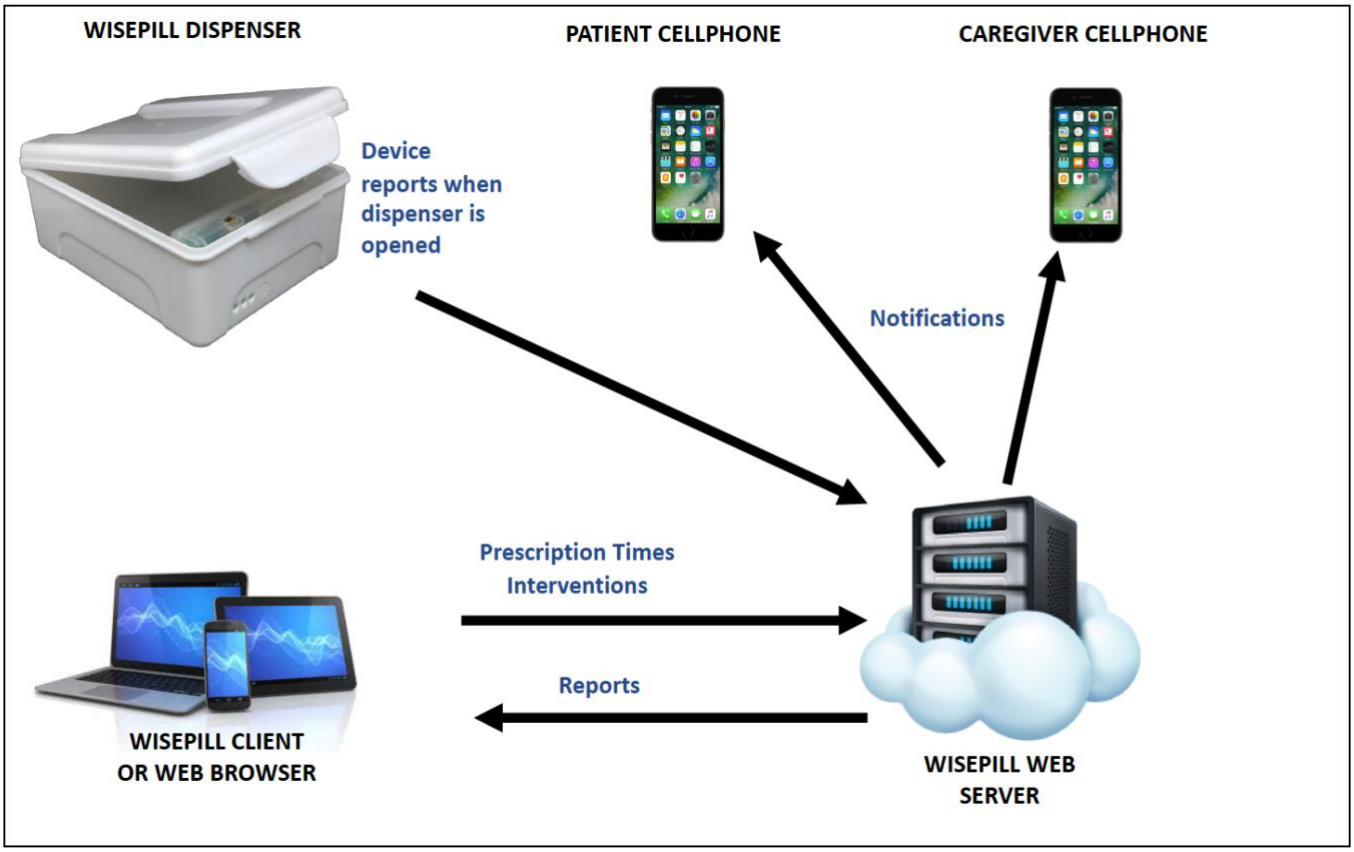
Yin, X., Tu, X., Tong, Y., Yang, R., Wang, Y., Cao, S., Fan, H., Wang, F., Gong, Y., Yin, P., & Lu, Z. (2012). Development and validation of a tuberculosis medication adherence scale. *PloS One*, 7(12), e50328. https://doi.org/10.1371/journal.pone.0050328

Yoeli, E., Rathauser, J., Bhanot, S. P., Kimenye, M. K., Mailu, E., Masini, E., Owiti, P., & Rand, D. (2019). Digital health support in treatment for tuberculosis. *New England Journal of Medicine*, *381*(10), 986–987. doi: 10.1056/NEJMc1806550

Zhou, C., Chu, J., Liu, J., Gai Tobe, R., Gen, H., Wang, X., Zheng, W., & Xu, L. (2012). Adherence to tuberculosis treatment among migrant pulmonary tuberculosis patients in Shandong, China: a quantitative survey study. *PloS One, 7(*12), e52334. https://doi.org/10.1371/journal.pone.0052334

APPENDICES

Appendix 1: The EvriMED Wisepill Box



Appendix 2: Previous Study Ethics Approval Letters

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Humanities
Fakulteit Geesteswetenskappe
Lefapha la Bomotho

Humanities 100
Since 1919

12 July 2021

Dear Ms TB Sole

Project Title:	Usability of a mHealth tool to support medication adherence schedules in newly diagnosed Tuberculosis (TB) patients
Researcher:	Ms TB Sole
Supervisor(s):	Prof TM Bakker Prof N Cassimjee
Department:	Psychology
Reference number:	04379055 (HUM009/0420)
Degree:	Doctoral

I have pleasure in informing you that the above application was **approved** by the Research Ethics Committee on 12 July 2021. Data collection may therefore commence.

Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the proposal. Should the actual research depart significantly from the proposed research, it will be necessary to apply for a new research approval and ethical clearance.

We wish you success with the project.

Sincerely,

Prof Innocent Pikirayi
Deputy Dean: Postgraduate Studies and Research Ethics
Faculty of Humanities
UNIVERSITY OF PRETORIA
e-mail: PGHumanities@up.ac.za

Fakulteit Geesteswetenskappe
Lefapha la Bomotho

Research Ethics Committee Members: Prof I Pikirayi (Deputy Dean); Prof KL Harris; Mr A Biggs; Dr A M de Beer; Dr A dos Santos; Ms KT Govinder Andrew; Dr P Gutuza, Dr T Johnson; Prof D Maree; Mr A Mohamed; Dr L Ngqondi; Dr C Puttergill; Prof D Reyburn; Prof M Sueu, Prof E Taljaard, Prof V Thebe, Ms B Tsebe, Ms D Mokalapa

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

Institution: The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.
- FWA 00002567, Approved dd 22 May 2002 and Expires 03/20/2022.
- IORG #: IORG0001762 OMB No. 0990-0279 Approved for use through February 28, 2022 and Expires: 03/04/2023.

Faculty of Health Sciences **Research Ethics Committee**

2 July 2021

Endorsement Notice

Dear Ms TB Sole

Ethics Reference No: HUM009/0420
Title: Usability of a mHealth tool to support medication adherence schedules in newly diagnosed Tuberculosis (TB) patients

The **New Application** as supported by documents received between 2021-02-15 and 2021-06-30 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on 2021-06-30 as resolved by its quorate meeting.

Please note the following about your ethics approval:
- Ethics Approval is valid for 1 year and needs to be renewed annually by 2022-07-02.
- Please remember to use your protocol number (HUM009/0420) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Ethics approval is subject to the following:
- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

On behalf of the FHS REC, Dr R Sommers
MBChB, MMed (Int), MPharmMed, PhD
***Deputy Chairperson** of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria*

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health).

Research Ethics Committee
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City of Ekurhuleni

GAUTENG PROVINCE

EKURHULENI HEALTH DISTRICT
RESEARCH PERMISSION

Research Project Title: Usability of a mHealth tool to support medication adherence schedules in newly diagnosed Tuberculosis (TB) patients.

NHRD No: GP_202103_053

Research Project Number: 06/04/2021-01

Name of Researcher(s): Ms Tebogo Brenda Sole

Division/Institution/Company: University of Pretoria

Date of review by the EHDRC: 30 March 2021

DECISION TAKEN BY THE EKURHULENI HEALTH DISTRICT RESEARCH COMMITTEE (EHDRC)

- This document certifies that the above research project has been reviewed by the EHDRC and permission is granted for the researcher(s) to commence with the intended research project.
- Facilities approved for the research: Daveyton Main Clinic, Dresser clinic, Esangweni CHC, Goba Clinic, Ramokonopi CHC and Tembisa main Clinic.
- Participants' rights and confidentiality must be maintained throughout the study period and when disseminating the findings.
- No resources (financial, material and human resources) from the health facilities will be used for the study. Neither the district nor the health facilities will incur any additional cost for the study.
- The study will comply with Publicly Financed Research and Development Act 2008 (Act 51 of 2008) and its related regulations.

Appendix 3: Current Study Ethics Approval Letters

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences

Institution: The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.
- FWA 00002567, Approved dd 18 March 2022 and Expires 18 March 2027.
- IORG #: IORG0001762 OMB No. 0990-0278 Approved for use through August 31, 2023

Faculty of Health Sciences **Research Ethics Committee**

13 July 2023

Approval Certificate
Annual Renewal

Dear Ms TB Sole,

Ethics Reference No.: HUM009/0420 – Line 1
Title: Understanding the usability of an mhealth tool to support medication adherence schedules in newly diagnosed tuberculosis patients: a mixed-methods retrospective study

The **Annual Renewal** as supported by documents received between 2023-06-22 and 2023-07-12 for your research, was approved by the Faculty of Health Sciences Research Ethics Committee on 2023-07-12 as resolved by its quorate meeting.

Please note the following about your ethics approval:
- Renewal of ethics approval is valid for 1 year, subsequent annual renewal will become due on 2024-07-13.
- Please remember to use your protocol number (HUM009/0420) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Ethics approval is subject to the following:
- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

On behalf of the FHS REC, Dr R Sommers
MBChB, MMed (Int), MPharmMed, PhD
***Deputy Chairperson** of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria*

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health)

Research Ethics Committee
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Gezina 0031, South Africa
Tel: 27 (0)12 356 3084
Email: deepika.behari@up.ac.za
www.up.ac.za

Fakulteit Gesondheidswetenskappe
Lefapha la Litsebene tsa Maphelo

Appendix 4: Tracking Log Sheet and Questionnaire

TRACKING LOG SHEET

ENROLMENT INFORMATION

Name & Surname: _____

Contact Number: _____

Facility name: _____

Facility ID: _____

Age: _____

Sex: _____

Date of Consent: _____ (DD-MM-YYYY)

Visit Number	Description	Visit date (DD/MM/YYYY)	Return date (DD/MM/YYYY)	Did patient return on the prescribed day? YES / NO. If no, WHY?
0.	Initiation (baseline)			
1.	Follow up and monitoring treatment			
2.	Follow up and monitoring treatment			
3.	Follow up and monitoring treatment			
4.	Follow up and monitoring treatment			
5.	Follow up and monitoring treatment			
6.	Follow up and monitoring treatment			
7.	Sputum collection for testing			

QUESTIONNAIRE

ENROLMENT AND FOLLOW-UP VISIT INFORMATION

A. Socioeconomic Data of TB Patients

Baseline Only

Questions	Questions and filters	Coding categories	Coding
1. Highest level of education	Indicate the level of education.	No Schooling	
		Completed Primary School	
		Completed Secondary School	
		Partially completed high school (Grade 10/11 but not matric)	
		Matric/Grade 12	
		Certificate Diploma	
		Bachelor's Degree	
		Post Graduate Degree	
2. Employment status	Ask the patient if they are currently employed. Indicate the status of employment.	Employed full-time	
		Employed part-time	
		Self-employed	
		Unemployed	
		Retired	
3. Marital status	Indicate the status	Married	
		Single	
		Living together with partner	
		Separated	
		Divorced	
		Widowed	
		Partner died	
4. Residential Conditions	What type of housing do yo live in? Is it a formal house or an informal settlement?	Brick house on separate stand	
		Flat	
		Townhouse Shack	
		Caravan / Tent	
5. Household Characteristics	What is the number of rooms available?		
	What is the number of windows available?		
	Do you live with other people in the house? If yes, write the number of people in the household.		

B.1. Adherence Data of TB Patients

All Visits

Questions	Questions and filters	Coding categories
1. Medication Adherence Self-Efficacy Scale Revised (MASES-R)	Measure patients' belief in their confidence to adhere to prescribed TB medications under a variety of challenging situations.	Refer to the instrument for administration and scoring of items.
2. TB-Related Stigma Scale (adapted version)	Measures the influence of patients' perception of the disease in relation to adherence and successful treatment outcomes.	Refer to the instrument for administration and scoring of items.

B.2. Adherence Data of TB Patients

All Visits

Questions	Questions and filters	Coding categories
3. Pill Count	Adherence assessment conducted by focal personnel and documented in the patient treatment card Record the number of pills (remaining) divide by the total pills given to patients in each month.	**Visit 1:** _____ (counted/total pills) **Visit 2:** _____ (counted/total pills) **Visit 3:** _____ (counted/total pills) **Visit 4:** _____ (counted/total pills) **Visit 5:** _____ (counted/total pills) **Visit 6:** _____ (counted/total pills)
4. Three-item Adherene Scale	The scale focuses on medication-taking behaviour and adherence. Items will be linearly transformed to a 0-100 scale with zero being the worst adherence, and 100 the best.	**Visit 1:** _____ (counted/total pills) **Visit 2:** _____ (counted/total pills) **Visit 3:** _____ (counted/total pills) **Visit 4:** _____ (counted/total pills) **Visit 5:** _____ (counted/total pills) **Visit 6:** _____ (counted/total pills)

Questions	Questions and filters	Coding categories	Indicate Yes / No
5. Self-report Questions	The two questions will be asked to patients, although they are phrased differently, they both are measuring whether the patient was adherent to medication-taking.	**Visit 1:** Have you completed all your medication for this month? Have you missed a dose(s) for this month?	
		Visit 2: Have you completed all your medication for this month? Have you missed a dose(s) for this month?	
		Visit 3: Have you completed all your medication for this month? Have you missed a dose(s) for this month?	
		Visit 4: Have you completed all your medication for this month? Have you missed a dose(s) for this month?	
		Visit 5: Have you completed all your medication for this month? Have you missed a dose(s) for this month?	
		Visit 6: Have you completed all your medication for this month? Have you missed a dose(s) for this month?	
6. Wisepill Adherence Measure	Record number of days the pill box was opened (intake), not opened (missed), reminder sms sent and whether if the patient opened the medication box following the reminder feedback.	**Visit 1:** _____(intake) _____(missed) Reminder SMS sent? If **Yes** was the medication box opened? **Visit 2:** _____(intake) _____(missed) Reminder SMS sent?	

Questions	Questions and filters	Coding categories	Indicate Yes / No
		If **Yes** was the medication box opened? **Visit 3:** _____(intake) _____(missed) Reminder SMS sent? If **Yes** was the medication box opened? **Visit 4:** _____(intake) _____(missed) Reminder SMS sent? If **Yes** was the medication box opened? **Visit 5:** _____(intake) _____(missed) Reminder SMS sent? If **Yes** was the medication box opened? **Visit 6:** _____(intake) _____(missed) Reminder SMS sent? If **Yes** was the medication box opened?	

C. TB Outcomes

Post 6 Months Treatment

Questions	Questions and filters	Coding categories	Tick Status
7. Overall treatment outcomes of patient diagnosed with TB Results availavle post month 6 of treatment	If completed treatment, what is the treatment outcome? **If <u>Cured</u>, it means 3 culture negative specimens** **If <u>Completed</u>, it means no culture results after treatment** *This information needs to be obtained from the Tier.Net database or from the patient self-reporting*	Cured	
		Treatment Completed	
		Treatment Failure	
		Died	
		Loss to Follow up	
		Transfer Out	
		Failure	
		Re-treatment	
		Resistant to Treatment	

Appendix 5: Medication Adherence Self-efficacy Scale Revised (MASES-R)

Purpose of the scale: *Medication Adherence Self-Efficacy Scale revised* (MASES-R), will be used to measure patients' belief in their confidence to adhere to prescribed TB medications under a variety of challenging situations. The scale has not been used in South Africa, however the instrument demonstrated good reliability with Cronbach's alpha coefficients of 0.92 and 0.90 at baseline and at 3-months respectively (Fernandez et al., 2008).

Scoring and interpretation: The instrument consists of 13-items measured on a 4-point Likert scale ranging from not at all sure to extremely sure. Twelve of the items ask about confidence in specific situations (e.g. busy at home, no symptoms, travelling), and one item asks about confidence in ability to make medication adherence a part of daily routine. There are no subscales on the measure, but rather the total scale score is computed by averaging across responses to all items. Higher scores indicate a greater level of self-efficacy.

Instructions for Administration

Situations come up that make it difficult for people to take their medications as prescribed by their doctors. Below is a list of such situations. We want to know your opinion about taking your tuberculosis medication(s) under each of them. Please indicate your response by checking the box that most closely represents your opinion. **There are no right or wrong answers.**

For each of the situations listed below, please rate how sure you are that you can take your tuberculosis medications **all of the time.**

Items	Not at all sure	A little sure	Fairly sure	Extremely sure
How confident are you that you can take your tuberculosis medications:				
1. When you are busy at home				
2. When there is no one to remind you				
3. When you worry about taking them for the rest of your life				
4. When you do not have any symptoms				
5. When you are with family members				
6. When you are in a public place				
7. When the time to take them is between your meals				
8. When you are travelling				
9. When you take them more than once a day				
10. When you have other medications to take				
11. When you feel well				
12. If they make you want to urinate while away from home				
Please rate how sure you are that you can carry out the following taks:				
13. Make taking your medications part of your routine				

Appendix 6: The Stigma Scale for Chronic Illnesses 8-Item Version (SSCI-8)

Purpose of the scale: Tuberculosis Stigma Scale for Chronic Illnesses measures internalised (3 items) and enacted (5 items) stigma experienced by people with neurological conditions. The scale has shown high internal consistency (Cronbach's alpha of 0.89). However, it has not been used in South Africa (Molina, Choi, Cella, & Rao, 2013).

Scoring and interpretation: The Stigma Scale for Chronic Illnesses 8-Item Version (SSCI-8). The items are scored on a 5-point Likert scale from 1 (never) to 5 (always). Total scores range from 8 to 40, with higher scores indicating higher levels of perceived stigma. The raw scores could be converted into IRT-based T-score distributions; standardised scores with a mean of 50 and a standard deviation of 10.

Instructions for Administration

A. Community perspectives on tuberculosis

Items	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
1. *Because of my illness, some people seemed uncomfortable with me.					
2. *Because of my illness, some people avoided me.					
3. **Because of my illness, I felt left out of things.					
4. *Because of my illness, people were unkind to me.					
5. *Because of my illness, people avoided looking at me.					
6. ***I felt embarrassed about my illness.					
7. ***I felt embarrassed because of my physical limitations.					
8. *Some people acted as though it was my fault I have this illness.					

***Enacted | ** Enacted/Internalised | *** Internalised**

Appendix 7: A Three-item Adherence Scale

Purpose of the scale: *A three-item adherence scale*, developed through rigorous cognitive interviewing and validated in the US (Fowler, Lloyd, Cosenza & Wilson, 2014; Wilson et al., 2014; Wilson et al., 2016) will be used to measure medication-taking behaviour and adherence. The scale has an internal consistency value of 0.86 for western sample (Wilson, Lee, Michaud, Fowler, & Rogers, 2016), it has also been previously used in South Africa (Phillips et al., 2017). The three items include (1) assessment of number of days medication was missed; (2) Frequency of medication intake and (3) Rating of adherence to medication intake in the previous 30 days.

Scoring and interpretation: The three adherence items will be linearly transformed to a 0–100 scale with zero being the worst adherence, and 100 the best (Gaito, 1980; Townsend, Hu & Evans, 1984). Summary of the scales is calculated as the mean of the three individual items.

Instructions for administration

Items	Available Response Options	Participant Responses
1. In the last 30 days, on how many days did you miss at least one dose of any of your TB medicines?	Number of Days (0-30)	
2. In the last 30 days, how good a job did you do at taking your TB medicines in the way that you were supposed to?	Very Poor = 1 Poor = 2 Fair = 3 Good = 4 Very Good = 5 Excellent = 6	
3. In the last 30 days, howe often did you take your TB medicines in the way you were supposed to?	Never = 1 Rarely = 2 Sometimes = 3 Usually = 4 Almost Always = 5 Always = 6	

Appendix 8: Interview Guide with Study Participants

Thank you for agreeing to participate in the study. We are interested in how feedback reminders and overall use contributed towards understanding barriers to adoption and sustainability of mHealth tool-Wisepill box.

End-user experiences

- What does the box represent to you? [probe: provide a metaphor to describe the box].
- What is your opinion of using the Wisepill box monitoring device? [probe: Is it easy or difficult to use the device?]
- How useful was the Wisepill box monitoring device to you?
- How do you feel about someone monitoring how you are taking your pills every day? [Whose involvement is triggered by sustained missed doses?]
- What was the reaction of people within your environment when they saw you using the device?
- Tell me about your storage strategies of the device when you were at home, work and when travelling.
- Would you say that Wisepill box monitoring device is appropriate for use among TB patients like yourself?

The influence of using mHealth tool

- What is your opinion about the importance of completing TB medication?
- Are you aware of the consequences of not completing your TB medication? [probe: Where did you obtain this information from? Do you know of any person who did not complete their TB medication? If yes, what happened to them? Do you think that incident motivated you to complete your TB medication?]
- In using the Wisepill box, were the reminder messages you received which were triggered by missed dose from the device useful? [probe: Did they help you to take your medication as prescribed?]
- If the reminders were not present, would you have still taken TB medication on that day? [probe: If no, what were some of the reasons that contributed to the non-adherent behaviour? If yes, what were some of the strategies you used to ensure you take TB medication?].
- Did the use of Wisepill box monitoring device motivate you to attend your scheduled follow-up clinic visit as prescribed?

Stigma and self-efficacy

- Did you feel embarrassed that you had TB? If so, why? [Probe: physical limitations that come with having TB]
- Did you feel that after having been diagnosed with TB, people around you treated you differently? [Probe: people avoided you, uncomfortable around you, said bad things about you – that it was your fault you contracted the disease]
- Did you believe that what people say about you in relation to the disease is true? If so, why?
- When you started with TB medication, were you confident that you will complete your medication as prescribed by the health care professional? If yes [Probe: highlight on motivations, goal attainment]
- Do you feel that having built this self-confidence before helped you complete TB medication?
- In your opinion what do you think made you stay adherent to TB medication over time? [probe: what situations make it easy for you to take your TB medication?]
- In your opinion what do you think made you not to stay adherent to TB medication over time? [probe: difficulties you have in taking TB medications? What situations make it difficult for you to take your TB medication?]

Sustainability

- What is the value of using Wisepill support technology in your everyday life? [probe: were you able to fit in the devise with your already present self-management health habits].
- How was your engagement/involvement in your own health care before and after the use of the Wisepill support device?
- Did you feel empowered when using Wisepill box device?
- How do you want your box to look like, if you could personalise it? [probe: elements such as size, alarms, structure of the box, colour etc.]
- What are some of the barriers you have experienced with using the device that makes you not to adopt the device? [probe: design, privacy and security issues, connectivity, personalisation].
- Despite the barriers mentioned, would you recommend the use of Wisepill box monitoring device to other people who are on TB treatment? Why / why not?

Appendix 9: Participant's Information & Informed Consent

ICD 5

PARTICIPANT'S INFORMATION & INFORMED CONSENT DOCUMENT FOR AN INDIVIDUAL IN-DEPTH INTERVIEW

Study title: Usability of an mHealth tool to support medication adherence schedules in newly diagnosed tuberculosis patients

Principal Investigator: Tebogo Brenda Sole, PhD Candidate

Institution: University of Pretoria, Department of Psychology

Supervisor: Professor Nafisa Cassimjee Tel: 012 420 2911| Email: nafisa.cassimjee@up.ac.za

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Office and Afterhours Telephone Number(s):

- **Office Numbers:** 012 339 8532 / 072 767 7780
- **Afterhours number:** 072 767 7780

Date and Time of First Informed Consent Discussion:

				:
date	**month**	**year**		**Time**

Dear Prospective Participant

1) INTRODUCTION

You are invited to volunteer to participate in a research study. I am doing this research for PhD degree purposes at the University of Pretoria. This form gives information about the study to help you decide if you would like to participate. Before you agree to take part in this study, you should fully understand what is involved. If you have any questions, which are not fully explained in this form, do not be shy to ask the researcher.

2) THE NATURE AND PURPOSE OF THIS STUDY

The aim of this study is to understand the influence of wisepill box feedback SMS reminders on TB patients' medication adherence, and to understand how you experienced using the box. By doing so, I wish to learn more about how feedback SMS reminders and overall use added towards understanding difficulties to adoption and sustainability of the wisepill box. A reminder again that the information on whether they are compliant/noncompliant to the treatment will not be reported to the facility-registered nurse.

3) EXPLANATION OF PROCEDURES AND WHAT WILL BE EXPECTED FROM THE PARTICIPANTS

If you agree to participate, you will be asked to participate in an individual interview which will take about 60-90 minutes. You will be interviewed by the researcher in a place that is private and easy for you to reach.

The individual interview will be a one-on-one meeting between the two of us. I will ask you several questions about the research topic. Examples of the questions include providing your opinion about using the Wisepill box. With your permission, the interview will be recorded to ensure that no information is missed.

4) RISKS AND DISCOMFORTS INVOLVED

There are no expected risks to participating in this study. However, if you feel uncomfortable because of the things discussed during the study, health care professionals' details (including mental health care) will be provided at the clinics. You will be informed of the contact details of health care and mental health care professionals at the clinic and these services will be available to you whether you are referred or not. Participation to the study is voluntary and you may stop participation at any time - this will not affect your planned clinic visits.

5) POSSIBLE BENEFITS OF THE STUDY

You may enjoy the benefit of using a Wisepill box that has potential towards improving your medication adherence and make adherence monitoring easier. Your experiences of using the device will contribute to research on supportive technology.

6) COMPENSATION

An inconvenience allowance of R100 (in a form of a gift voucher that will enable you to buy from selected shops like Shoprite, Checkers, Usave, or OK) will be given to you at the end of the study.

7) VOLUNTARY PARTICIPATION

The decision to take part in the study is voluntary. You can also stop at any time during the interview without giving a reason. You will still receive normal care and treatment for your illness at the clinic. All the records and data linked to you in the study will be destroyed if you choose to withdraw.

8) ETHICAL APPROVAL

This study was approved by the University of Pretoria at the the following Faculties:

- *Postgraduate Research Ethics (PG-ResEthics) Committee of the Faculty of Humanities* (Tel: 012 420 4853, Email: PGHumanities@up.ac.za)
- *Faculty of Health Sciences Research Ethics (ResEthics) Committee* (Tel: 012 356 3084 or 012 356 3085, Email: fhsethics@up.ac.za)

9) INFORMATION ON WHO TO CONTACT

If you have any questions about this study, you should contact:

- Name: **Ms. Tebogo Sole**
- Institution: **University of Pretoria**
- Email: **u04379055@tuks.co.za and/ tebogobrendasole@yahoo.com**
- Telephone: **012 339 8532**
- Cell: **072 767 7780**

10) CONFIDENTIALITY

We will not record your name anywhere and no one will be able to connect you to the answers you give. Your answers will be linked to a unique barcode ID or a pseudonym (another name) and we will refer to you in this way in the data, any publication, report or other research production. Furthermore, text message reminders will not be related to TB, but will be in a quote form – to protect your status. An attention sign will be placed outside the wisepill box and you will be told to store the box safely at home.

The researcher will be the only person with access to the tape recorder and/or recordings. The recordings as well as transcription will be stored in a password-protected computer. All records from this study will be treated as secret. Results will be printed in journals or presented at conferences in such a way that it will not be possible for people to know that you were part of the study.

The records from your participation may be reviewed by people responsible for making sure that research is done properly, including members of the Research Ethics Committee. All these people are required to keep your identity secret. Otherwise, records that identify you will be available only to people working on the study, unless you give permission for other people to see the records.

All hard copy information will be kept in a secured locked facility as decided by the University of Pretoria, for a minimum of 15 years and only the research team will have access to this information.

11) CONSENT TO PARTICIPATE IN THIS STUDY

- I confirm that the person requesting my consent to take part in this study has told me about what the study entails, any risks or discomforts, and the benefits of the study.
- I have also received, read and understood the above written information about the study.
- I have had enough time to ask questions and I have no doubts to participate in this study.
- I am aware that the information taken in the study, including personal details, will be secretly processed and presented in the reporting of results.
- I understand that I will not be punished in any way should I wish to stop taking part in the study and removing myself from the study will not affect the treatment and care I receive at the clinic.
- I am participating willingly.
- I have received a signed copy of this informed consent agreement.
- I understand that the individual in-depth interview or discussions will be recorded. I give consent that it may be recorded.

Participant's Name (please print)	**Participant's Signature**	**Date**

Researcher's Name (please print)	**Researcher's Signature**	**Date**

Appendix 10: Certificate for Good Clinical Practice (GCP) Beginners' Course Level 2

Good Clinical Practice Certificate 2021

This is to certify that

TEBOGO SOLE

Successfully completed the following *Level 2* course

Good Clinical Practice: Beginner Course

Focus on current SA GCP; SA ethical & regulatory documents.
Full incorporation of ICH GCP and other international guidance and regulatory documents.

Facilitator: Dr HD Geldenhuys **Date:** 26&27 May 2021

CREDE
Clinical Research Education and Development

Teaching Clinical Research to All

Accredited by SMLTSA appointed by the PBMT HPCSA: MTS 21/001

"This ICH E6 GCP Investigator Site Training meets the Minimum Criteria for ICH GCP Investigator Site Personnel Training identified by TransCelerate BioPharma as necessary to enable mutual recognition of GCP training among trial sponsors."

This certificate is valid for 3 years.