Adapting, Refining, and Piloting an Interactive Digital Adherence Technology to Facilitate Patient-Centered Tuberculosis Care in Papua, Indonesia

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Abstract

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Background: Tuberculosis (TB) was responsible for approximately 1.3 million deaths globally in 2022, making it the leading cause of mortality among individuals with HIV and a significant contributor to deaths associated with antimicrobial resistance. Adherence to the full treatment regimen is essential to prevent the development of resistance and improve cure rates. In Papua, the eastmost province in Indonesia, TB treatment success rates have consistently fallen short of national standards. The World Health Organization recommends Digital Adherence Technology (DAT) as one of the patient-centered care approaches. One such tool currently under evaluation is the Tuberculosis Treatment Support Tools (TB-TST), which combines mobile applications for patients and providers with a home-based urine test to detect drug metabolites and confirm adherence remotely. The increasing internet access and smartphone ownership in Papua

highlights the potential for utilizing this tool. However, adaptation and refinement are necessary to ensure its effective implementation in Papuan communities.

Purpose: The primary objectives of this dissertation were to adapt, refine, and evaluate the TB-TST to facilitate and enhance patient-centered TB care in Papua.

Method: This dissertation employed a multi-phase approach. First, a scoping review was conducted to identify gaps in TB mHealth apps in Indonesia. This review informed the adaptation and refinement phase, which utilized thematic analysis to categorize app features and functionality. Second, the TB-TST was adapted and refined through three rapid iteration phases for patient and provider interfaces. This process involved participatory design activities with design experts and end-users (TB patients and providers) and included usability testing. Third, through a single-arm prospective pilot study, the final phase assessed the usability, feasibility, acceptability, and further refinement of the refined TB-TST (Samocare app).

Results: study 1: The scooping review of TB mHealth apps in Indonesia highlighted a lack of patient-centered applications that facilitate communication and collaboration between patients and providers or include strategies to verify treatment adherence. Additionally, none of the applications identified were tailored or tested for end-users in Papua. Study 2: In the second study, we addressed the gap identified in the first study by adapting and refining the TB-TST to be culturally and contextually appropriate for the community in Papua. Study 3: The findings of the third study suggested that the Samocare intervention was feasible, acceptable, and perceived as useful. Patients and treatment supporters reported that the application facilitated patient-centered care by improving communication and providing tailored support.

Conclusion: The findings from this study offer preliminary evidence suggesting that transforming TB care in Papua is now achievable/feasible. This study is the first to employ

Human-Centered Design principles through rigorous, iterative research phases involving end-users (TB patients and care providers) and design experts in Papua. Although the final test demonstrated the intervention's usefulness, feasibility, and acceptability, further research is necessary. Specifically, a larger, adequately powered clinical trial is required to test the intervention comprehensively, and implementation research is needed to evaluate its effectiveness and sustainability in improving TB care in Papua.

DEDICATION

To the TB patients and their families who generously shared their time and personal stories, and to the dedicated TB nurses in the clinic who offered their dreams, hopes, experiences, and tireless care: I extend my deepest gratitude. I hope that by sharing this research journey, we can contribute to improving the status of TB in Papua.

To Papua, the land that nurtured me with its beautiful and unique way of life: I hope this research can bring even a small benefit to this incredible land, allowing us all to lead healthier lives and showcasing the impressive beauty of Papua, the true land of paradise.

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Chapter 1. INTRODUCTION

1.1 BACKGROUND

Tuberculosis (TB) remains a public health challenge with an estimated 10.6 million people fell ill with TB and caused 1.3 million deaths globally in 2022. TB was the leading cause of death among people with HIV and a major cause of antimicrobial resistance-related death.[1] In United States (USA) during 2023, TB case counts increased among all age groups and has not yet achieved the 2025 national target of less than 1.3 TB cases per 100,000. The Center of Disease Control (CDC) reported that overall TB incidence in USA was 2.9 TB cases per 100,000 persons.[2] While TB is preventable and curable, there is a lot of work that needs to be done to achieve the ambitious global goal of ending the TB epidemic by 2030. The first pillar of the ending TB strategy is integrated patient-centered care and prevention, including assuring treatment of all people with TB.[3] TB treatment is currently affordable and widely accessible; nonetheless, taking all the medications for TB therapy is difficult, because treatment regimens are long, the daily pill burden is high, social and negative stigma and chance to develop drug resistance (DR-TB) with more frequent and serious adverse drug reactions resulting in social and economic costs to patients.[3,4]

Indonesia has the second highest TB burden following India with over 1 million people infected with TB in 2022.[1] In 2023, in an effort to reach the target of ending the TB global epidemic by 2030, the government of Indonesia pushed for an improvement in the case detection rate. The next step after detection is to ensure those with TB start and complete the treatment. Adherence to the full course of treatment is critical. Consequences of poor adherence or treatment abandonment include increased chance to develop DR-TB with longer treatment and

more serious adverse drug reactions, increased mortality, and morbidity. Several factors contributed to poor adherence in Indonesia, such as lack of support, the stigma of TB, public private-mix data (where private practices often do not report new TB cases or TB patients registered in both public and private facilities, thus being counted twice), socio-economic burden, a challenging geographical condition with poor transportation infrastructure, complicated administration process in health care service, lack of attention from health care providers due to an overload of patients, and low level of TB knowledge.[5-9] In 2022, Indonesia had a treatment success rate 87% for drug susceptible TB and 47% for DR-TB.[10] If assessed by province, the success rate ranges from 72% to 96%.[10]

One of the provinces contributing to the low treatment success rate is Papua (shown in Figure 1.1), as the region was called until 2023, before it was split into four different provinces: Papua, South Papua, Central Papua and Highland Papua province), with rates consistently below 78% (figure 1.2).[10] All data and research activities in this study was collected and conducted prior to Papua divided into four different provinces.

Figure 1-2: Map of Papua Province

Source: Papua in Figure-BPS, 2022

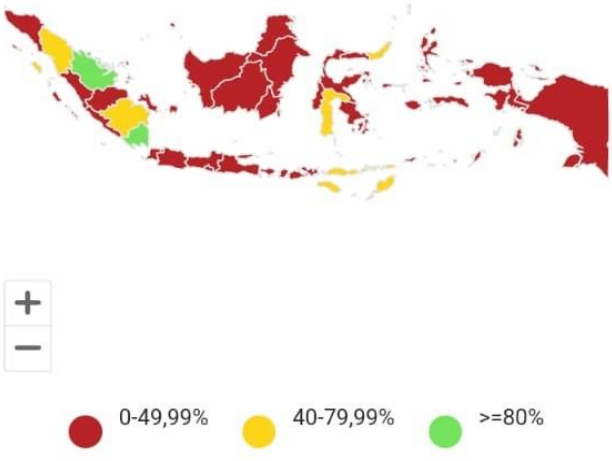

Figure 1-1: Map of Treatment success rate in Indonesia 2022

Source: Dashboard TB, 2022

Papua province is one of the provinces situated in Papua Island, positioned in the easternmost region of Indonesia. The island is commonly regarded as one of the less developed areas in Indonesia. Based on the Presidential Regulation Number 60 on Underdeveloped Regions, 62 regencies in Indonesia falling under rural classification, , among which 30 are situated on Papua Island, inclusive of 22 regencies within Papua province.[11] (Figure 1.3) According to data from the 2022 census, Papua's population is approximately 4.42 million, with Jayapura city contributing the highest proportion at around 9.30 percent of the total population. The workforce predominantly engages in the agricultural sector, with approximately 1.29 million individuals employed in this field.[12]

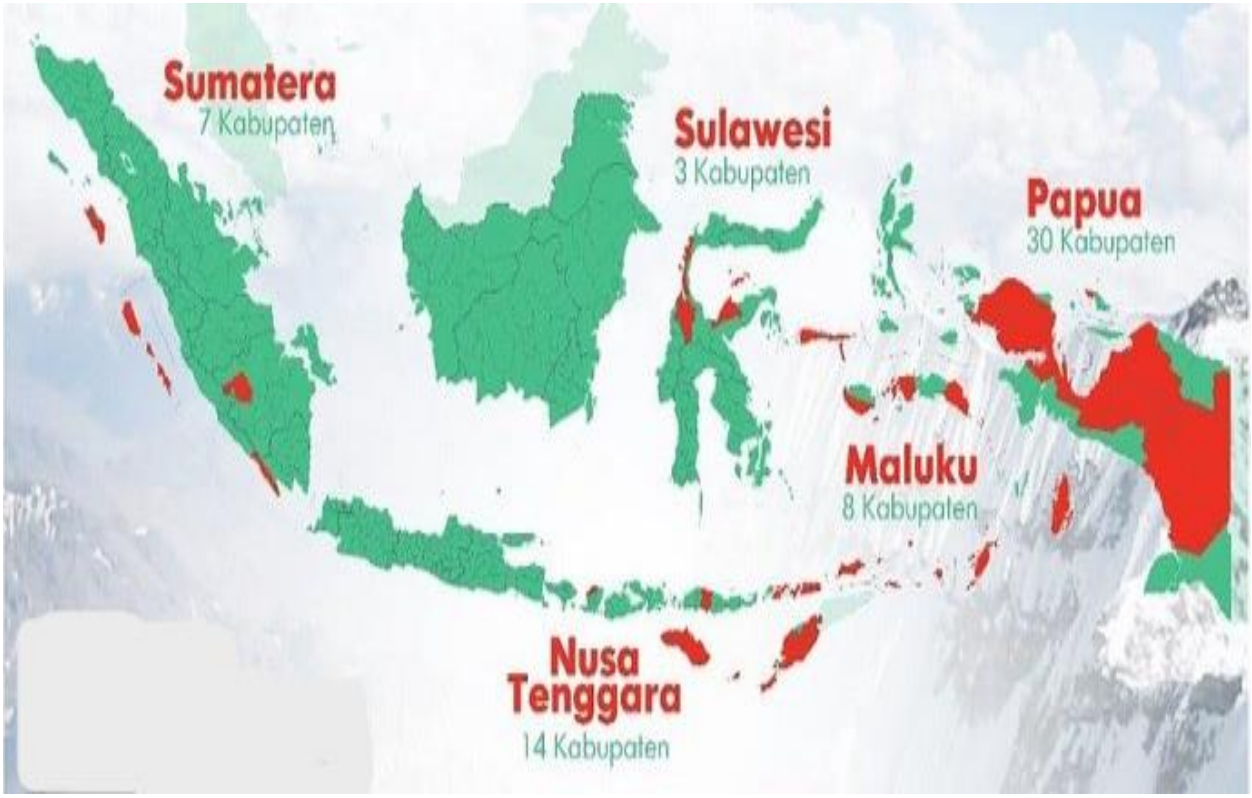

Figure 1-3: Map of Underdeveloped Regions in Indonesia 2020-2024 based on Presidential Regulation Number 60 year of 2020 with red indicated as underdeveloped regions.

Source: www.ditjenpdt.kemendesa.go.id, 2021

Papua island stands out as a uniquely diverse region within the country, characterized by significant ethnic diversity among indigenous Papuan groups who largely maintain and practice their traditions and culture. This indigenous diversity is further enriched by immigrants from Java and other islands, creating a complex social mosaic. Historically, voices of Papuans have been marginalized in broader Indonesian politics and development initiatives. Despite being considered a rural region with limited resources, it is unclear why Papuans experience higher rates of disproportionate health outcomes,[13,14] including TB. Effective healthcare programs, including those aimed at improving TB outcomes, must resonate with the Papuan culture and acknowledge this diversity to foster pride and enthusiastic engagement among the local populations. While research on TB in Papua is limited, existing studies suggest several factors contributing to non-adherence. These include challenges in accessing healthcare service due to geographical barriers and travel costs, limited TB knowledge among patients due to insufficient education from healthcare providers, lack of family support, and differences in drug administration methods. [15,16]

Furthermore, Papua is known as one of the less developed provinces in Indonesia, and the advancement of digital infrastructure remains notably limited and disparate. This can be attributed to the challenging geographical landscape, characterized by rugged mountains, isolated and widely dispersed settlements, and susceptibility to security disruptions. Consequently, the utilization of digital technology is primarily concentrated within urban areas.[12] Despite the region's remoteness, several urban areas in Papua have seen improvements in internet access and increased smartphone ownership with the availability of 5G cellular network coverage (figure 1.4)[17], highlighting potential avenues for leveraging technology to address healthcare

challenges.[18]

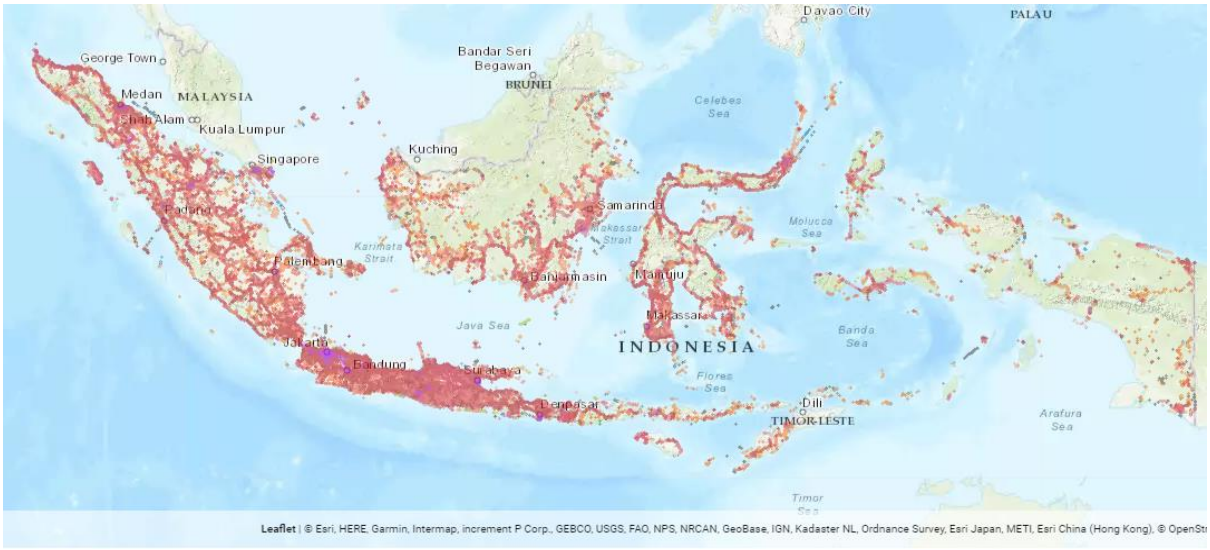

Figure 1-4: Map of 4G/5G cellular network coverage distribution in Indonesia with red dots illustrated the availability of 4G/5G mobile network services in the region.

Source:www.nperf.com, 202

Given Papua's historical challenges with low treatment adherence rates and persistent health inequities, there is an urgent need for innovative solutions to tackle these issues. In 2016, the World Health Organization (WHO) advocated for the adoption of a people-centered care approach to combat the global TB pandemic.[19] This approach emphasizes addressing the health needs and expectations of individuals and communities, rather than solely focusing on patients or diseases. It acknowledges that TB care should be tailored to meet the needs, values, and preferences of affected individuals, ensuring their rights are protected to facilitate successful treatment outcomes and enhance their overall well-being and financial risk protection. One particularly promising avenue for supporting this people-centered approach to care involves leveraging digital technology, specifically Digital Adherence Technologies (DATs).[3]

Recommended by the WHO in 2017, DATs can be incorporated into healthcare systems with the aim to improve treatment adherence among individuals with TB. Research on DATs has

shown promising results, including improved outcomes among high-risk patients, reduced travel costs, enhanced patient-provider interaction, and promotion of patient-centered care when combined with health behavior interventions.[20-23] Among DATs, mobile health applications (mHealth apps) have been tested and widely utilized to improve treatment adherence for various chronic diseases, such as asthma, heart failure, hypertension, and HIV. [24] While the impact of DATs in improving TB treatment adherence is mixed and requires further research, they still represent a promising solution for improving medication adherence. [24-27] [28]

One DAT that has been iteratively developed with user-centered design principles to support individuals with TB is the Tuberculosis Treatment Support Tool (TB-TSTs) intervention. The intervention includes an interactive mobile health application for individuals with TB, a drug metabolite test to confirm adherence remotely, and a dashboard for treatment supporters.[29] Main features of the app include education on TB and its treatment, treatment adherence tracking, self-reported treatment side effects, interactive messaging with treatment supporter and anonymous support group discussions. The TB-TST intervention was initially developed for a Spanish speaking population in Argentina and is being evaluated in a pragmatic randomized clinical trial and has been shown to be feasible and acceptable. To ensure its applicability in a different setting and population, it needs to be adapted and refined to meet the community's needs.

To adapt and refine the TB-TST for the Papuan population, we used the Discover, Design, Build, and Test (DDBT) framework (Figure 5) based on human centered design (HCD) Principles.[30] The three phases of DDBT framework are intended to gather the requisite information to drive iterative redesign of existing evidence-based interventions or implementation strategies to improve usability and implementation outcomes while retaining an intervention core component. Target stakeholders are engaged in each phase to ensure that the proposed solutions meet the needs of the stakeholders and are easy to use and understand.[30]

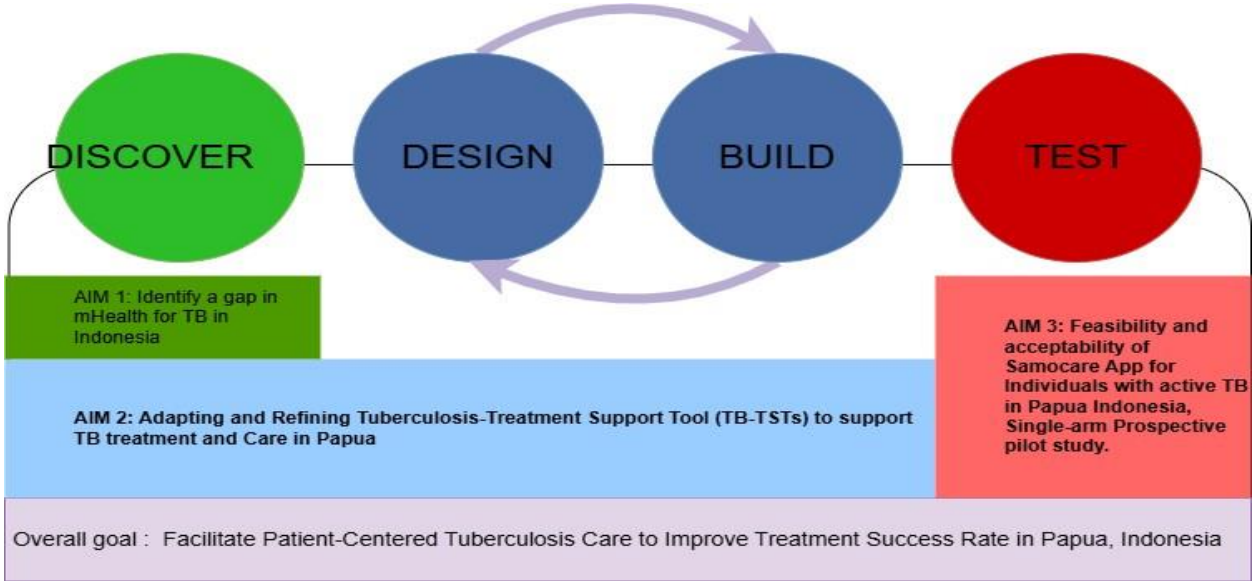

Figure 1-5: The adaptation and refinement of TB-TSTs within the context of Discover, Design Build, and Test Framework.

Figure 5 illustrates the individual aims and the overall goals of this dissertation research, which is to facilitate patient-centered TB care in Papua using digital adherence technology to improve TB treatment success rate. Following the phases in the DDBT framework, this dissertation is comprised of two main parts. The first focused on the Discover and Design+Build phases, addressing Aims 1 and 2. The second part of the study focused on the Test phase, completing Aim 3.

1.2 OVERVIEW OF CHAPTERS

Chapter 2, "Review of mobile health apps to support TB prevention and care in Indonesia," addresses Aim 1 in the DDBT framework, which is to identify needs and gaps to be addressed, in this case understanding the landscape of mHealth for TB in Indonesia. This study was a scoping review of available TB mHealth apps in Indonesia. The gaps identified in this phase were then used to inform aim 2.

Chapter 3, "Adapting and refining TB-TSTs to support TB treatment and care in Papua," addresses Aim 2 in the DDBT framework, which is Discover, Design and Build. This study to adapt and refine an existing DAT for the Papuan context consisted of three rapid iteration phases for both patient and provider app interfaces using participatory design activities with design experts and end users (TB patients and providers) and usability testing.

Chapter 4, "Feasibility and Acceptability of an Interactive Digital Adherence Technology (Samocare App) for Patients with Active Tuberculosis in Papua, Indonesia: Single-Arm Prospective Pilot Study," addresses Aim 3, which is to test the intervention in a real-world context. We conducted a single-arm prospective pilot study to assess the usability, feasibility, and acceptability of the intervention and identified what worked, what didn't and future recommendations.

The final chapter, "Conclusion," provides a summary of the main findings and implications for future research.

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Chapter 2. MOBILE HEALTH APPLICATIONS TO SUPPORT TUBERCULOSIS PREVENTION AND CARE IN INDONESIA: A SCOPING REVIEW

2.1 ABSTRACT

Background: Tuberculosis continues to pose a significant global health challenge, with over 1 million deaths reported in 2022. Despite efforts to combat TB pandemic, Indonesia has the second-highest TB burden in the world. Recognizing the potential of mobile health (mHealth) applications in addressing TB challenges, especially given the increasing ownership of smartphones, we conducted a scoping review to assess the landscape of mHealth apps supporting TB care in Indonesia. The objectives were to identify existing TB apps, evaluate their features, understand their role in supporting treatment adherence, and determine areas of unmet needs in the Indonesian context.

Method: In October 2022, a comprehensive search on the major Indonesia app suppliers, Google Play Store and Apple store, was conducted and updated in April 2023 following the PRISMA(Scr) guidelines. The search aimed to identify mHealth apps specifically designed to support TB care in Indonesia, using a set of eight keywords. Thematic analysis was used to identify and evaluate features of various apps. For apps offering treatment adherence features, we searched for relevant publications to identify their development process and evaluate their effectiveness.

Result: Twenty-two apps met the inclusion criteria and were included in this analysis. Among these, eight focused on treatment adherence; sixteen on TB education and awareness; ten on care navigation; five on a communication and community forum; seven for e-consult/telehealth; four

were self-screening tools; four for data reporting, monitoring, and evaluation; and five included other features. Apps primarily developed and targeted users from the western part of Indonesia. **Conclusion:** There was an increase in new apps from 2020 reflecting progress to address TB in the country. However, several issues were identified including apps no longer accessible, lack of systems to ensure confidentiality, and apps including inaccurate information. Findings highlighted a gap of patient-centered apps that facilitate patient-provider communication and collaboration or include a strategy to verify treatment adherence. No app was identified that was tailored for Papua, a culturally unique province of Indonesia, with the lowest treatment success rates. Given Indonesia's diverse culture, varied geography, and unique societal nuances, a user-input driven developing approach is crucial to ensure the digital tools are tailored to effectively address the specific needs and preferences of Indonesian users.

2.2 INTRODUCTION

Tuberculosis (TB) is a preventable and curable disease. However, it remains a public health crisis with a total of 1.3 million people died in 2022, making TB the second leading infectious killer after COVID-19.[1] In the effort to end the global TB epidemic, the World Health Organization (WHO) set a target for reduction in number of TB incidence rate by 80% in 2030.[2] To reach the target to end the global TB epidemic, Indonesia's government has strengthened the effort by securing the high level of support that led to the enactment of the Presidential decree number 67 in 2021 which emphasizes boosting innovations to enhance the effectiveness of TB interventions that prioritize patient-centered approaches.[3] Despite the efforts made, Indonesia is still the second leading country with a high TB burden after India, with the TB incidence in 385 per 100.000 population in 2022.[4]

The WHO has advocated for the expanded use of digital technologies, including mobile health (mHealth) applications, to support the End TB strategy.[5] In general, the use of mHealth apps has been increasing due to the advantage of technology and extensive smartphone ownership. A growing body of literature examining mHealth apps suggests their potential to increase the accessibility of services, [6-8] provide health-related recommendations, reduce stigma, improve convenience and easy access to healthcare services, improve time and cost efficiency, improve community engagement increase independence, enhance consistent monitoring from the healthcare providers and self-monitoring by patients, and improve treatment adherence.[9-12] The use of these tools grew during the COVID-19 pandemic in response to the need to provide health services remotely.[13,14] Despite the challenges such as dependency on geographic region, internet access needs, user characteristics, technical issues, lack of regulatory and security concern, and maintaining engagement,[12,15-18] mHealth apps still provide an opportunity to improve patient health and enable healthcare providers to perform their duties efficiently.[19]

Digital technologies, especially mHealth apps, play a pivotal role in supporting TB prevention and care in areas such as early diagnosis, treatment adherence, contact tracing, and educational awareness.[9,20] These technologies have been recommended as part of tools to enhance patient-centered approached in TB.[21] A descriptive review of mHealth app globally for improvement of TB treatment and care highlighted several purposes of the TB mHealth apps including monitoring patients' adherence, dosage adjustment, eLearning/information, tuberculosis diagnosis, and other related purposes.[22,23] Importantly, one of the key benefits of mHealth apps in TB care is the enhancement of medication adherence.[24] Several studies have examined TB mHealth apps and other digital technologies; [25,26] however, research on the effectiveness of mHealth apps for TB care, especially in high-burden countries like Indonesia,

remains limited. This gap underscores the necessity for comprehensive evaluation of TB-related mHealth apps available in the Indonesian market, one of the largest smartphone markets in Asia.[27] In addition, treatment adherence is a critical factor in the global fight against TB. Indonesia stands with an 87% treatment success rate and a 47% success rate for DR-TB,[4] highlighting the need for ongoing efforts to improve treatment outcomes. Digital adherence technologies (DATs) offered by mHealth apps present an opportunity to support treatment adherence. However, the development of a comprehensive app that promotes patient-centered care is essential to enhancing TB treatment adherence in Indonesia.

This scoping review aims to bridge the gap in our understanding of mHealth apps for TB prevention and care in Indonesia. By (1) identifying available TB apps, (2) examining their features, (3) understanding their role in supporting treatment adherence, and (4) determining areas of unmet needs, this review seeks to inform digital technology development and foster innovative approaches to strengthen Indonesia's TB prevention and care program. Through a detailed analysis, we aim to provide insights into how mHealth apps can be tailored to the specific needs of end-users, contributing to the global effort to end the TB epidemic.

2.3 METHOD

2.3.1 *Study design.*

We conducted a scoping review to assess publicly available mHealth apps, following the Preferred Reporting Items For Systematic Reviews and Meta-Analyses extension for Scoping Review (PRISMA-ScR).[28] Our systematic steps included conducting searches within the Android (Google Play Store) and iOS (Apple App Store) platforms available in Indonesia, screening of search results using established inclusion criteria, downloading the eligible apps, and subsequent thematic analysis for app feature grouping. For identified apps with treatment

adherence support features, we conducted literature searchers to identify publications related to the app development or evaluation.

2.3.2 *Eligibility criteria and information sources:*

Eligibility criteria included being focused on TB care or contained features about TB in Bahasa (Indonesian's language), and any release date. We considered all publications on apps supporting TB treatment adherence from PubMed and Google Scholars, spanning all years and languages.

2.3.3 *Search and data charting process:*

In October 2021 an Independent review (Author AS) conducted searches of both stores using the following terms: "Tuberkulosis", "TBC" "Pengobatan TBC" "TB", "Tuberculosis", "TB Indonesia", "Tuberkulosis Indonesia", "TBC Indonesia". The search was updated in April 2023. Apps that met inclusion criteria were listed and reviewed. Duplicates were removed based on the logo and name. After all duplicates were removed, we listed the final apps and downloaded them to conduct a detailed review. We collected information based on the description in the app stores and found more information on their websites or YouTube for the apps with unclear descriptions and/or required registration to access the app. The following information was extracted for our analysis: app functionality, last updated, star rating, total reviewers, total downloads, age rate, registration requirement, app target population, and features offered. We extracted information about the development and evaluation of the app for any publication.

2.3.4 *Synthesis of results/analysis:*

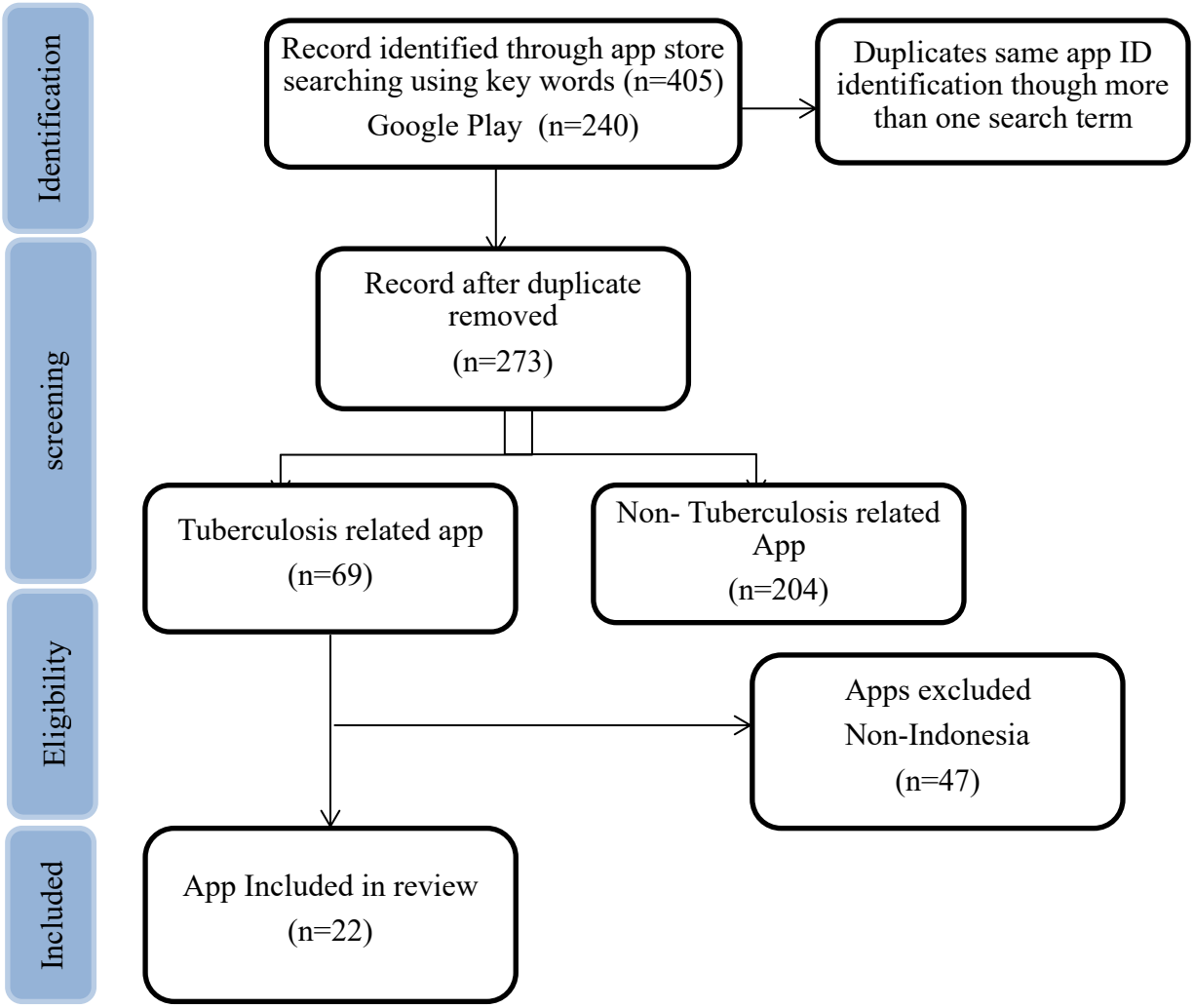
We used thematic analysis to categorize the apps according to their predominant features. Specifically addressing our inquiry into apps supporting treatment adherence, we provided a

detailed description of such apps. Additionally, we identified gaps to inform feature needs for future TB apps and summarized relevant published literature about the apps.

2.4 RESULT

We identified 22 apps focused on TB available for use in Indonesia from the 405 apps returned in the searches. Of the 273 apps remaining after deduplication, 69 were related to TB, and of those 48 were excluded because they were not for use in Indonesian (Figure 3.1). App selection flow diagram).

Figure 2-1: selection process



2.4.1 *Apps characteristics:*

All the apps were available on Google Play Store and free to download. Three of the apps were also available in the Apple store. The number of apps released per year varied over the previous 5 years with three (14%) up to and including 2018, three (14%) in 2019, seven (32%) in 2020, two (9%) in 2021, six (27%) in 2022 and one in 2023. Of the apps that had reviews, 12 (55%) and ten (45%) did not have star ratings. Ten apps (47%) required registration or login. For apps with star ratings, one had more than 450 reviews, one had 268 reviews, and the remaining had less than 100 reviews. Regarding the number of downloads, one app (5%) had 100K+ downloads, one (5%) had 10K+ downloads, and 14 were downloaded less than 100 times. For target users, 17 apps (77%) were targeted at the general population, potential TB and TB patients, and four linked to healthcare providers. Five apps (23%) were intended to be used by healthcare providers. Two apps were released for DR-TB care management. Four apps (18%) could not be opened and one warned of bugs-related problem. Eleven apps (50%) showed evidence of maintaining regular updates, six apps (27%) had not been updated since their release, and five apps (22%) were only updated within the 20 days period after being released. None of the apps were developed in Papua. A detailed summary of all apps reviewed is presented in **Multimedia Appendix 1 & 2**.

2.4.2 *Thematic analysis of functionality.*

We categorized the features included across the apps into 8 main categories: treatment adherence, education and awareness, care navigation, communication and community forum, e-consult/telehealth, self-screening tool, data reporting, monitoring and evaluation, and other features. (Table 3.1)

Table 2-1 Categorization of the included apps (n=22)

Feature Offered	Description	N (%)	Name of the apps
Treatment adherence	Features to support and motivate individuals with TB or DR-TB to adhere to their medication schedule consistently and complete treatment	8 (36%)	TB-ZONE, EMPATI-TB, Bye TBC!, tbc counter, Zero TB, Sembuh TB, Berantas TB, EMPATI CLIENT
Education and Awareness (Education hub)	Information on TB, including drug resistance, TB guidelines, health tips for Individual with TB, their family or community.	16 (73%)	Sobat TB, Dasboard TB Indonesia, TB-ZONE, Empati TB, SIPARU (Sistem Pakar Tuberculosis), Bye TBC!, tb counter, Ramuan Herbal TBC Paling Mujarab, Peduli TB, Sembuh TB, Lapor TBC.id, MOIST TB, Berantas TB, Pantau TB, EMPATI CLIENT, SI BESTIE
Care Navigation	Offer guidance to help individuals access healthcare facilities or emergency contacts.	10 (45%)	Sobat TB, WIFI TB, SIPARU (Sistem Pakar Tuberculosis), Entb (e-notification Tuberculosis), Bye TBC!, TIBIKU TB Screening for you, tbc counter, PTB (Peduli TB), Lapor TBC.id, Berantas TB
Communication and community forum	A communication platform within an app or linked WhatsApp group designed as a discussion forum for various groups.	5 (23%)	Sobat TB, tbc counter, Lapor TBC.id, MOIST TB, EMPATI TB
e-consult / telehealth	A consultation feature that enables users to seek health advice.	7 (32%)	Sobat TB, TB-ZONE, SIPARU (Sistem Pakar Tuberculosis Paru), TIBIKU (TB Skrining Untukmu), si BESTIE (Aplikasi Bebas TB), PTB (Peduli TB), MOIST TB, EMPATI-CLIENT
Self-screening tool	A quiz-based test designed to determine if a person might have TB	4 (18%)	TB-ZONE, EMPATI-TB, Bye TBC!, tbc counter, Zero TB, Sembuh TB, TIBIKU TB screening
Data reporting, monitoring and evaluation	Features that enable healthcare providers to perform data recording, reporting, monitoring, and evaluation tasks efficiently	4 (18%)	WIFI TB (Wajib Notifikasi TB), EMPATI-TB, entb (e-Notifikasi Tuberculosis), Pantau TB.
Other features	Features that do not fall into big category such as exercise, sample tracking, nutrition tracker, education quiz, selling products, tool to calculate TB drug, legal advice	5 (23%)	Sembuh TB, Lapor TB, BERANTAS TB, SITRUST, PIKRU

2.4.2.1 Treatment adherence related features

Eight apps offered treatment adherence features (Table 3.2). Most apps had alarm reminders (7, 88%) for users to set their preferred time for medicine reminders. Apps like Sembuh TB and TB counter linked the alarm reminder with medication intake reporting for patients. Patients could click to report taking the medication when the reminder notification popped up on their phones. EMPATI-TB and EMPATI CLIENT were developed by one non-profit organization that runs a TB program in Indonesia to monitor, record, report, and mentor DR-TB patients. Healthcare providers use EMPATI-TB to monitor the patients, while EMPATI-CLIENT is for the DR-TB patients to report their daily medicine intake through synchronous or asynchronous video observed treatment (VOT). Apart from EMPATI TB and EMPATI CLIENT, the remaining apps focus on patients with drug-susceptible TB and only three of the apps had feature for self-reporting medication intake. In addition, none of the apps intended for drug-susceptible TB patients reported how to verify the medication intake self-report from the patient.

Among the eight apps with treatment adherence features, release dates were from 2020 to 2022. Three of these apps had not been updated since their release, four had updates in 2022, and one in 2023.

Two publications were identified on apps that specifically provided a treatment adherence support feature. One article presenting a preliminary study of the Sembuh TB app reported that, out of 45 recruited users, 10 (22%) maintained app usage over three months, exhibiting better treatment adherence for three months compared to non-users in the clinic (100% compared to 83%, respectively). However, it was limited to a small sample size, encompassing both patients with drug-susceptible TB and those with DR-TB. Additionally, the evaluation period for the use of the interventions was limited to just three months [29]. The second article detailed the

development cycles of the BERANTAS TB app using Software Development Life Cycle Method with user acceptance testing.[30]

Table 2-2 Detail Treatment adherence functions, n=8

App Name/Component review	TB-ZONE	EMPATI-TB	Bye TBC!	tbc counter	Zero TB	Sembuh TB	BERANTAS TB	EMPATI CLIENT
release date	9-Feb-20	1-Jul-20	19-Feb-19	25-Nov-21	25-Jan-22	17-Oct-22	16-Jan-20	22-Mar-21
update year	19-Feb-20	16-Aug-22	3-Feb-20	25-Nov-21	25-Jan-22	7-Jan-23	16-Jan-20	28-Sep-21
# of days from the latest update from release date	10	776	349	0	0	82	0	190
Rating star	5	4.3	5	5	NA	NA	5	NA
Downloads	100+	1K+	1K+	10+	10+	100+	100+	100+
Alarm reminder	✔	X	✔	✔	✔	✔	✔	✔
Calendar	X	X	X	X	x	✔	✔	✔
Medication tracking history	X	✔	X	✔	X	✔	✔	✔
appointment track	X	X	X	X	X	✔	X	X
Video Observed Treatment (VOT)	X	✔	X	X	X	X	X	✔
provider report	X	✔	X	X	X	X	X	X
Medication take report	X	✔	X	✔	X	✔	✔	✔
Treatment milestone tracker	✔	✔	X	✔	X	✔	X	X
Only for DR-TB patient	✔	✔	X	X	X	X	X	✔
Publication	✔	X	X	X	X	X	✔	X

2.4.2.2 Education and Awareness (Education Hub)

Most apps (16, 72%) offered specialized features focusing on education and awareness about TB. These apps provide valuable information about the disease including its causes, risk factors, symptoms, diagnostics, treatment, and prevention. Two apps (10%) focused on educating healthcare providers about specific TB and DR-TB care management guidelines. The two apps

went beyond general information and provided information about traditional medicine practices and the legal rights of individuals affected by TB. One government-developed app included access to current data, facts, statistics, and the overall status of TB in Indonesia.

Each app had a specific target audience, ranging from the general population to individuals diagnosed with TB, families or individuals impacted by TB, and healthcare providers. These apps' information and educational content were delivered through various engaging formats, such as articles, news, videos, pictures, comics, and podcasts. In terms of source of education content, six apps (27%) did not provide the source of information and we cannot describe the source of education content for four apps (18%) due to request login. In addition, two apps (10%) no longer could be opened.

2.4.2.3 Access to care navigation

Ten apps (45%) had specific features to guide users on how to access healthcare facilities and emergency contact. Each app had varying ways to navigate accessing TB care. For examples, users could access the information about all the health facilities in Indonesia that offered TB treatment or only specific health facilities, or the nearest healthcare centers based on the user's location. Further, each app had different search methods for accessing the navigation, including keyword-based searches, lists of contact information, navigation links to Google Maps for location-based services, social media links, and direct access to contact information through WhatsApp.

2.4.2.4 Communication and community

Five apps (23%) offered community support features with communication capabilities. These apps employed different communication platforms, including from in-app communication to linked WhatsApp groups. The discussion group varied from general, where everyone concerned

with TB can be involved, to a group where the TB survivors can share their experiences and tips to help those who undergo the treatment to encourage treatment completion. For instance, Sobat TB provided a communication forum for TB survivors and individuals affected by TB, including family members or parents. Additionally, another app had a forum that could be used by active TB patients that required registration for access.

2.4.2.5 e-consultation/telehealth

Seven apps (32%) offered e-consultation or telehealth features within their platforms. Each app utilized a distinct mechanism to facilitate access to e-consultation services. For instance, EMPATI-CLIENT enabled patients to send direct messages to healthcare providers, Sembuh TB allowed users to reach out to healthcare providers, including medical doctors and nutritionists, for reporting or seeking assistance or reporting side effects. Moreover, apps with self-screening capabilities integrated an e-consultation feature when a person was identified as potentially having TB. Consultations could be conducted through messaging or video calls. A few provided a direct link to WhatsApp for users to request further information or guidance.

2.4.2.6 Early diagnosis (Screening)

Four apps had self-screening features with a quiz-based test (a series of Yes-No questions) that assessed the likelihood of a person having TB. Once the test was completed, if the results suggested a potential TB case, the user received a detailed explanation, urging them to contact the nearest healthcare provider, or it would offer a direct link to contact healthcare providers for immediate assistance.

2.4.2.7 Data report, monitoring, and evaluation

Three apps aimed to strengthen the Indonesian TB program by facilitating data reporting, monitoring, evaluation, and contact tracing activities. EMPATI TB was launched to support

healthcare providers and community workers in effectively monitoring and evaluating DR-TB patients and recording all the activities and communication among providers. WIFI TB and ENTB (e-Notifikasi Tuberkulosis) primarily focused on improving the public-private mix reporting system, enabling private healthcare facilities to report their TB cases and suspected TB patients to the government with fewer administrative barriers and improved efficiency.

2.4.2.8 Other apps targeting healthcare providers and others.

Five apps (23%) have features that did not fall into the main categories identified in this review. For example, the PIKRUI app is used as a guideline in calculating appropriate dosing for TB patients and other related pulmonary diseases. The SITRUST app tracks samples for lab tests. One app also has additional features such as calculating nutrition, exercise, and an online store to sell products from the specific pharmacy brand that sponsored the app's development. Another app provided legal consultation for reporting mistreatment or injustice for TB patients.

2.5 DISCUSSION

In this mHealth app review we identified 22 mHealth apps focused on TB-related care in Indonesia. A prior review conducted by Keutzer in 2020,[31] which covered all TB-related apps worldwide, had identified five from Indonesia. Among the five apps included in this previous review, four were no longer available on the Google store. Our findings reported that six apps were developed prior to 2020, while the subsequent sixteen were published from 2020 to 2023, indicating a notable increase in the number of apps over the last few years. All the apps were free to download and available on Android, the operating system most often used in the smartphones available in Indonesia.[27,32] TB predominantly affects individuals from low socioeconomic backgrounds[33-35] and TB care and treatment is in general provided free of charge; therefore, it is expected that all the TB apps in Indonesia are available free of charge. However, some of the

apps had technical issues such as not being able to be opened and the record of apps update history revealed that many apps had not been updated since their initial release or had not performed updates for over a year as of our last data collection in April 2023. This raises concerns about app maintenance, and whether these apps are current, compatible, relevant, and secure.

Based on the WHO TB guidelines for 2022, the goal of health education is to provide essential information, empowering patients to make informed decisions.[21] Extensive global literature has shown that improved knowledge about TB is associated with better treatment adherence and completion rate.[36-39] In Indonesia, studies have shown that health education is linked to adherence and completion rate,[40-42] as well as a reduction in TB stigma.[43] Improving TB patient knowledge is crucial not only for patients themselves but also for their families, relatives, and the public. It is a positive where most of the apps we reviewed provided education features; however, it was essential to carefully review the content of education to ensure accuracy and relevance. Almost half of the apps had not been updated after they were released. Lack of updating ultimately raises concerns about the currency and reliability of the educational content or the guidelines for healthcare providers. It is concerning that some apps do not provide the sources of their educational content, which can contribute to misinformation and unfounded beliefs. For instance, one app promoting herbal/traditional medicine for TB treatment could lead individuals away from seeking proper medical care and treatment. The Indonesia health ministry has offered TB education content, including videos and pictures.[44] Reliable sources limit the ambiguity of educational materials and ensure accurate information reaches the public. Enhancing the quality and credibility of education features is vital to empowering both TB patients and their families with accurate information for better health outcomes. In addition, it is

important that app developers consider the educational content and TB guidelines from the Health Ministry for their apps, which is publicly available.

The WHO recommends a patient-centered approach to TB care to allow all individuals with TB to exercise their rights to receive treatment and care.[45] Our review found that less than half of the TB apps available in Indonesia include a care-navigation feature, and about one third offer e-consult or telehealth features. However, several apps are exclusively focused on a single health facility, primarily located in the western part of Indonesia, which raises questions about the preferences of end-users from the eastern regions, such as Papua. Some apps with telehealth linked to the WhatsApp were exclusive and limited to users with familiarity of this platform. Additionally, while self-screening features in four apps provide initial assessment for TB detection, there was a risk of misinterpretation without clear guidelines for follow-up, echoing challenges observed with self-testing in the other health context.[46]

Social support is recognized as crucial for a person/patient to finish the TB treatment successfully.[47] Considerable research has focused on social support groups' effect on motivating TB patients from other patients, TB survivors, and others such as family members or close friends where TB patients have better outcome and seeking behavior when supported by the family and community.[47-50] Five apps provided discussion forums to allow app members to discuss either specific or general TB, such as tips and sharing experiences. Some of the apps with discussion features only allow those who registered to be involved in the discussion forum. However, it is unclear how the app presents the identity of each person in the discussion forum and how the discussion contents of the forum are monitored. It is crucial to carefully consider how messages are communicated in these forums. Given the persistent stigma associated with TB, revealing personal identities could potentially lead to stigmatizing behavior and affect the

credibility of contribution. Therefore, it is critical to prioritize and address significant concerns regarding data security and privacy.

Indonesia implemented the DOTS program as the national TB control strategy to ensure that TB patients take their medication under the supervision of a healthcare worker or a treatment supporter. However, with the high numbers of TB cases, providing DOTS in person by healthcare workers can be logistically challenging. Thus, family members were utilized as treatment supporters. This condition is challenging as one factor contributing to non-adherence is lack of support from family or community.[51] In addition, several studies which were carried out failed to provide strong evidence of the effectiveness of DOT in several methods (family DOT, community DOT, or DOT at health facility) compared to self-administered in improving treatment adherence.[52-54] With the recommendation to utilize technology, the availability of several apps in Indonesia have indicated the commitment to provide alternative treatment administered. A patient centered approach was promoted in an alternative to DOTS to tailor the method of supervision and administration treatment while emphasizing the importance of patient-care provider working together to reach collaborative care. Thus, mHealth as one alternate digital adherence tool should accommodate this principle. However, apps available in Indonesia mostly only provided basic features for patients with less evidence of interactive features to support patient-provider interaction. Only two apps have featured communication with providers and one app for VOT, yet only for DR-TB patients. In addition, none of the apps with the self-report medication feature (besides the app for DR-TB that has VOT feature), provided a method to verify if the patient takes the medication at home. The absence of detailed documentation on the app development, especially for apps that provided treatment adherence features, make it difficult to understand whether the available apps in Indonesia sufficiently meet

the specific needs of TB patients and healthcare providers. One app described the development and testing of the app yet did not make clear if it is being tested to the end-users, which should include those impacted with TB such as patients, family, or healthcare providers.

2.6 LIMITATION

This study has limitations that should be considered when interpreting the results. First, our search was limited to mHealth apps that were available on an app store (Android and iOS store). We may have missed apps available by other methods that are not published or in use such as web-based apps. Second, for the apps requiring login, we were unable to log in and had to rely on the features reported in the product description and YouTube videos. In addition, several apps appeared to no longer be maintained and available and were unable to be opened. Although we relied on features and functionality of these apps (for example, YouTube videos), we may not have captured complete information about the flow of the apps and how they work.

2.7 CONCLUSION

There was an increase in new apps from 2020 reflecting progress to address TB in the country. However, several issues were identified including apps being no longer accessible, a lack of systems to ensure confidentiality, and apps including inaccurate information. Findings highlighted a gap of patient-centered apps that facilitate patient-provider communication and collaboration or that include a strategy to verify treatment adherence. No app specifically tailored for Papua, a unique province of Indonesia known for its diverse and distinct culture, was identified, despite having the lowest treatment success rates. Given Indonesia's diverse culture, varied geography, and unique societal nuances, a user-input driven developing approach is

crucial to ensure the digital tools are tailored to effectively address the specific needs and preferences of Indonesian users.

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Multimedia Appendix 2-1. Multimedia Appendix 1: mHealth app characteristics : yes (v), no (x)

Name item extracted	Sobat TB	Dashboard TB Indonesia	TB-ZONE	SITRUST	WIFI TB (Wajib Notifikasi TB)	EMPATI-TB	SIPARU (Sistem Pakar Tuberkulosis Paru)	entb (e-Notifikasi Tuberkulosis)	Bye TBC!	TIBIKU (TB Skrining untukmu)	Si BESTIE (Aplikasi Bebas TB)	PIKRUI	tbc counter	Ramuan Herbal TBC Paling Mujarab	PTB (Peduli TB)	Zero TB	Sembuh TB	Lapor TBC.id	MOIST TB	BERANTAS TB	PANTAU TB	EMPATI CLIENT
release date	5/14/20	12/8/20	2/9/20	10/11/17	4/21/22	7/1/20	12/7/19	5/15/20	2/19/19	11/2/17	8/15/22	3/2/17	11/25/21	10/5/19	8/19/22	1/25/22	10/17/22	12/6/22	2/7/23	1/16/20	8/19/20	3/22/21
update year	5/18/22	1/29/23	2/19/20	12/21/20	4/12/23	8/16/22	12/11/19	12/3/21	2/3/20	11/2/17	8/24/22	7/9/20	11/25/21	10/5/19	8/28/22	1/25/22	1/7/23	3/6/23	2/23/23	1/16/20	8/19/20	9/28/21
# days update from released	734	782	10	1167	356	776	4	567	349	0	9	1225	0	0	9	0	82	90	16	0	0	190
Rating star	2.3	4.4	5	3.8	4.3	4.3	NA	NA	5	4.9	NA	5	5	4.6	NA	NA	NA	NA	NA	5	NA	NA
reviewer	464	17	17	268	15	6	NA	NA	104	32	NA	49	6	5	NA	NA	NA	NA	NA	10	NA	NA
give 5 reviews	133	14	17	142	10	5	NA	NA	104	30	NA	49	6	3	NA	NA	NA	NA	NA	10	NA	NA
give 1 review	293	2	0	47	0	1	NA	NA	0	0	NA	0	0	0	NA	NA	NA	NA	NA	0	NA	NA
Downloads	100K+	1K+	100+	10K+	5K+	1K+	50+	100+	1K+	100+	50+	1K+	10+	1K+	50+	10+	100+	10+	10+	100+	50+	100+
age rated	12+	3+	3+	3+	3+	3+	3+	3+	3+	3+	3+	3+	12+	3+	3+	3+	3+	3+	3+	3+	3+	3+
need to login	YES	NO	NO	YES	YES	YES	NO	YES	YES	NO	YES	NO	YES	NO	YES	YES	YES	NO	NO	NO	YES	YES
Education and awareness	v	v	v	x	x	v	v	x	v	x	v	x	v	v	v	x	v	v	v	v	v	v
Access to Care Navigation	v	x	x	x	v	x	v	v	v	v	x	x	v	x	v	x	x	v	x	v	x	x
Communication and community engagement	v	x	x	x	x	x	x	x	x	x	x	x	v	x	x	x	x	v	v	x	x	v
e-consult/ telehealth	v	x	v	x	x	x	v	x	x	v	v	x	x	x	v	x	x	x	v	x	x	x
early diagnosis (self screening	x	x	v	x	x	v	x	x	v	v	x	x	v	x	x	v	v	x	x	x	x	x
Treatment adherence	x	x	v	x	x	v	x	x	v	x	x	x	v	x	x	v	v	x	x	v	x	v
Data report, monitoring and evaluation	x	x	x	x	v	v	x	v	x	x	x	x	x	x	v	x	x	x	x	x	v	x
other features	x	x	x	x	x	x	x	x	x	x	x	v	x	x	x	x	v	v	x	x	x	x

Multimedia Appendix 2-2. Name of mHealth apps, Link and about the app from the developer.

No	Name app	Link app	About App (explanation from the store)
1	Sobat TB	Sobat TB - Apps on Google Play	Get access to comprehensive information about Tuberculosis (TBC) disease with SobatTB! Just a click away - you will discover all about TBC, for free! Whether you're just want to know about TBC or you are a TBC patient, this application offers you a full-package of TBC overview. Explore and join our patient community thread for an experience of information exchange with a larger society. Browse through our complete health facilities list (hospitals, primary healthcare, clinics) to identify the closest doctor to your location. SobatTB is developed by Yayasan KNCV Indonesia (Indonesian KNCV Tuberculosis Foundation) aiming to promote easier access to TBC information for everyone through Android-based app. The main users of this app, including public, TBC patients, healthcare officers, TBC communities, as well as DKI Jakarta Province Health Office. Menu 1. Articles - Browse comprehensive information about causes, symptoms, transmission, and treatment of TBC 2. Healthcare Facilities - Search easily for Hospitals, Primary Healthcares, and Clinics by location from all over Indonesia and sorted it by the closest to your location - Gain information about location, contact, rating, and review of healthcare facilities, as well as its availability for BPJS health insurance - Rate and review healthcare facilities you've visited 3. Community - Join community threads discussing any TBC issues, including stories and experiences from TBC patients - Ask for any questions that you may want to know about TBC - Share your experiences in visiting healthcare facilities
2	Dashboard TB Indonesia	Dashboard TB Indonesia - Apps on Google Play	The TB Indonesia Mobile Dashboard application is intended to provide convenience for the public and stakeholders at various levels, starting at the national, provincial, district / city level, and at the health facility level so that they can quickly monitor the progress of TB indicator achievement and respond based on credible data. Managed by the Sub Directorate of Tuberculosis, Directorate of Direct Communicable Disease Control (P2ML), Directorate General of Disease Prevention and Control, Ministry of Health of the Republic of Indonesia.
3	TB-ZONE	TB-ZONE - Apps on Google Play	Tb-zone is an application that provides information about Pulmonary Tuberculosis. Inside there are articles regarding information on pulmonary TB, quizzes about pulmonary TB, TB detection, and reminders to take medication that can help people recognize and be more aware of pulmonary tuberculosis.

4	SITRUST	SITRUST - Apps on Google Play	SITRUST (Tracking Information System for Transport Specimens) is an information system for monitoring the movement of test sample package shipments starting from the order process, courier pick-up, confirmation of receipt, feedback related to the condition of the test sample to the recapitulation of the test sample inspection results. SITRUST consists of a web-based application form for managing SITRUST user data and accounts and an Android-based mobile application used to send and receive test samples. The main users of this information system are program management officers and laboratory analysts from health facilities (PKM, Labs, Hospitals, Clinics, Lapas), couriers, the Health Office and the TB Sub-Directorate. Apart from functioning as a tracking tool, SITRUST also supports the recapitulation of recording and reporting of sending test samples electronically. SITRUST was developed using the latest open technology and uses the internet network so that the application can be used by many users according to their duties and responsibilities. In addition, SITRUST is also designed to be simple and user-friendly so that it is easy for all types of users to use.
5	WIFI TB (Wajib Notifikasi TB)	WIFI TB (Wajib Notifikasi TB) - Apps on Google Play	WIFI TB (TB Notification Mandatory) is an alternative mobile application for reporting suspected, diagnosed, and TB patients by Independent Practitioners and Clinics who have not used SITB and are limited in human resources and infrastructure and/or contributions only until the discovery of a suspect.
6	EMPATI-TB	Tuberkulosis - Android Apps on Google Play	EMPATI (E-TB Mobile for TB Patient Assistance) is an information system to help monitor, record reporting and mentoring TB RO patients to ensure patients complete treatment. EMPATI is designed simple and user friendly and can update and access data and information wherever and whenever needed.
7	SIPARU (Sistem Pakar Tuberkulosis Paru)	Sistem Pakar Tuberkulosis Paru - Apps on Google Play	Lung Tuberculosis (SiParu) Expert System
8	entb (e-Notifikasi Tuberkulosis)	e-Notifikasi Tuberkulosis - Apps on Google Play	e-Notification Tuberculosis(eN-TB) is a device-based application that aims to facilitate private practitioners (PPs), both in independent practice and private clinics, to record and notify TB suspects/patients online. The features of the eN-TB application consist of: (1) recording and reporting TB suspects/patients to the appropriate primary health care facility (Puskesmas) without any territorial boundaries; (2) storing patient identity to support patient adherence to treatment; (3) displaying a list of recorded patient data. This application was developed by the Tuberculosis Working Group, Infectious Disease Research Center, Faculty of Medicine, Universitas Padjadjaran through the e-ASIA Joint Research Program funding scheme, that consist of grants funds from the Ministry of Research, Technology and Higher Education Republic of Indonesia , Otago University, and Harvard University. This application was built as an instrument for a project titled "Increasing Notifications of Tuberculosis from Private Practitioner" (INSTEP2). This application is expected to increase TB cases' reporting, which can contribute to the efforts to eliminate TB in Indonesia. In the initial stage, this application can be accessed on a limited basis by doctors who participate in the INSTEP2 project.
9	Bye TBC!	Bye TBC! - Apps on Google Play	Bye TB! is a companion application for taking medication for TB patients and Superintendents of Drug Swallowing (PMO). Not only that, this application can also be used by the general public. In this application there is information about TB, remedies for medication, articles about TB, information on community health centers, and quizzes to test the extent of understanding related to TB disease.

10	TIBIKU (TB Skrining untukmu)	TIBIKU TB Screening For you - Apps on Google Play	TiBiKu was initiated by Care Cluster RSUD Ciracas. The Care Cluster itself is a Quality Assurance Group (GKM) established on March 31, 2016 to implement GKM (Quality Control Group - 8 Steps and 7 Tools) in solving problems and finding solutions so that innovations will arise that will increase Productivity, quality and service quality of RSUD Ciracas. The Care Cluster consists of: Chairman: dr. Aditya Galatama Purwadi, MARS Secretary: Rut Agusta, Amd Members: 1. Ns. Santi, S.Kep 2. Curiani Marbun, S.Hut 3. Lia Purwanti, S. Kom 4. M. Fachrul Astamar, ST 5. Veny Hidayanti, S.Pd While the Facilitator of Cluster Care is dr. Dian Rahmawati who is the Head of Service Unit of IGD and Outpatient of RSUD Ciracas.
11	Si BESTIE (Aplikasi Bebas TB)	SI BESTIE Aplikasi Bebas TB - Apps on Google Play	The SI BESTIE application (TB Free Application) has three features to support Tuberculosis (TB) prevention and control services, namely: Tuberculosis (TB) symptom self-screening feature, digital patient treatment data feature, and information feature about TB which contains information important for the prevention and treatment of TB. The SI BESTIE application is an android-based application that connects patients with health workers in order to improve TB suspect case finding and optimize TB disease treatment and control. This application has 2 user pages, namely: patient pages and health workers. The SI BESTIE application is developed and designed to be simple and user-friendly. It aims to facilitate the treatment and control of Tuberculosis (TB) disease services. Created by : dr. Armando Hadyono Joko Sasmito Kediri, East Java, Indonesia
12	PIKRUI	PIKRUI - Apps on Google Play	Spirometry: normal value prediction and calculation based on Pneumobile Project, Chemotherapy dose for NSCLC based on PDPI guideline - Chemotherapy dose for Thymoma based on Persahabatan Hospital SOP - PORT Score - Anti Tuberculosis Drug cat.I and II - Infusion Drug calculation (Norepinephrine)
13	tbc counter	tbc counter - Apps on Google Play	tbc counter patient monitoring application in the scope of the health center that is integrated with the web

14	Ramuan Herbal TBC Paling Mujarab	Ramuan Herbal TBC Paling Mujar - Apps on Google Play	TRADITIONAL MEDICINAL PLANTS TO TREAT ANNUAL CHRONIC LUNG TB Breath is the source of life if humans still breathe can be sure to be alive, and one important component for breathing is the lungs and if the lungs are disrupted then they should be treated immediately before getting worse. The lungs are very important and vital organs. Lung disease that is not treated immediately will disrupt overall body performance. Unfortunately lung medicine is not a cheap drug, not to mention the costs incurred for disease observation. Fortunately, nature also provides various types of plants that can be processed into traditional medicines to treat lung disease naturally. With a little effort, you can cultivate these plants yourself according to your needs. On the other hand, increasingly sophisticated modern medicine makes the quality of life for people with lung disease better. Therefore it is highly recommended for patients to combine medical treatment with traditional medicine. Lung disease drugs have traditionally been chosen in general because they are cheaper and easier to obtain.
15	PTB (Peduli TB)	Peduli TB - Apps on Google Play	The PTB (Tuberculosis Care) application is one of the information, education and health promotion services related to tuberculosis (TB) which is designed in five sub menus including detailed information on tuberculosis; educational videos; self-screening; provision of health facility information services; and telemedicine connected to a pulmonologist.
16	Zero TB	Zero TB - Apps on Google Play	#monitoring of patients #medical Application for patient monitoring and notification of drug use based on Android. You are a doctor and are required to interact with your patients in drug consultations? This application is the answer Video consultation feature with WhatsApp and notification of drug use to remind patients to take their medicine on time This will make it easier for patients and doctors to carry out their duties.
17	Sembuh TB	Sembuh TB - Apps on Google Play	“Sembuh TB”- An Open for Public Android smartphone application, designed to increase medication adherence for Tuberculosis patients in Indonesia. This app was created to ease the process of taking medicine by providing a positive experience for patients; offering virtual consultation from the doctors & dietitians; sending reminder of medication and hospital visit schedule; provision of information about nutrition, health & disease; and connecting nutrition & health shop (Otsuka Products). Features: 1. Alarm Notification 2. Calendar 3. E-Consultation with doctor and dietitian 4. Recipes Innovation 5. Nutrition & Health Video 6. Exercise Studio 7. Nutrition & Health Shop 8. Nutrition & Health Articles 9. Food Calculator

18	Lapor TBC.id	TB indonesia - Android Apps on Google Play	This is a free digital platform for the general public, especially for the people affected by TB in Indonesia that provides users access to the following: - Information about TB and TB prevention - Information on rights of people affected by TB - Chat forum for people affected by TB - Location of health centers (DOT centers) offering TB services - Ability to report barriers to access TB services including stigma faced in any setting - Be notified about TB updates - Be notified about updates NOTE: We are not making any medical recommendations. If you have any medical concerns, please consult a doctor before making any medical decisions.
19	MOIST TB	MOIST TB - Apps on Google Play	MOIST TB is a revolutionary application that optimizes education about Tuberculosis. With an easy-to-use interface and accurate information, we can help people understand and solve this problem. This application brings new solutions in the fight against Tuberculosis and ensures that everyone has equal access to quality information.
20	BERANTAS TB	berantas TB - Android Apps on Google Play	Application to eradicate TB! Is an Informative Application about Tuberculosis (TB) that can be accessed by cell phone, without any charge. With a simple display, TB Eradication has several features namely TB info, Medication Reminder, Calendar, PKM Kamsaw, and Quiz. In addition there are also some educational videos in it. The existence of the application eradicate TB! this is expected to make it easier for the public to obtain TB information, as well as for patients to be reminded of taking medication. The main user of the TB Eradicate application! These are the general public, TB patients, and health care workers especially in the Kampung Sawah Public Health Center.
21	PANTAU TB	PANTAU TB - Apps on Google Play	Pantau TB is an application for Puskesmas, Cadres and TB Patients in monitoring TB patient treatment, starting from patient identity to sputum examination and taking medicines for. Patients will be notified if they have not taken the medicine and check sputum at the 2nd and 5th months TB cadres will receive the same notification as TB patients as a whole the patients managed by this cadre Puskesmas will get the same notification as TB patients as a whole. TB patients in the puskesmas area. Puskesmas can also manage its cadres.
22	EMPATI CLIENT	EMPATI CLIENT - Apps on Google Play	EMPATI CLIENT is a medication attendance application for TB patients. By using this application, patients can take daily medication, view a list of medication history, and consult directly with cadres or assistants.

Chapter 3. ADAPTING AND REFINING TUBERCULOSIS-TREATMENT SUPPORT TOOLS (TB-TSTS) TO SUPPORT TB TREATMENT AND CARE IN PAPUA, INDONESIA

3.1 ABSTRACT

Introduction: The Tuberculosis (TB) Treatment Support Tools (TB-TST) intervention is an interactive digital adherence technology to support individuals with active TB that was developed for and with a Spanish speaking population and found to improve treatment outcomes in a clinical trial in Argentina. This tool offers a promising alternative patient-centered care strategy to address the persistently low TB treatment success rates in Papua, Indonesia with increasing smartphone ownership and internet access. However, to ensure the applicability of TB-TST within Papua's community, an adaptation and refinement process is necessary.

Methods: We used a mixed-method approach guided by the Discover, Design/Build, and Test (DDBT) framework to adapt and refine the TB-TST patient and treatment supporter interfaces for a Papua context. After translating all text to Bahasa Indonesia, to adapt the patient interface, we conducted usability testing with ten individuals with TB, five design experts, and participatory design sessions with seven TB nurses. Findings informed the development of a low-fidelity prototype for the second phase. To solicit feedback and preferences on the low-fidelity prototypes, another cycle of usability testing was conducted with six individuals with TB and three TB nurses. After refinement, we conducted field testing by trialing the app in the clinic for a week with nine participants. We conducted daily evaluations and analyzed data based on prioritized issues.

Result: The iterative participatory evaluation phases led to several major refinements of the app interface including rearranging and enlarging buttons and icons, revising the side effects list,

reorganizing the information page, updating educational content, and adding daily behavioral motivational messages on the homepage. For the treatment supporter interface, significant refinements included the addition of a page with a list of patients filtered by priority issues with different kinds of symbols, correction of side effects, adding an appointments scheduler feature, and a mobile-optimized alternative to the computer-based interface.

Conclusion: The iterative cycles resulted in significant refinement and tailoring for the Papua's setting and readied the tools for formal evaluation in a pilot study with newly TB-diagnosed patients for the full 6-month courses of treatment to assess the usability, feasibility, acceptability, and further refinement needs.

3.2 INTRODUCTION

Indonesia is the second highest tuberculosis (TB) burden country after India, with approximately one million people infected with TB in 2023.[1] The Indonesian government made a strong commitment to end the global TB epidemic in 2035 by enacting Presidential regulation to strengthen the National TB Program, involving efforts from all levels of both government and the community.[2] Assuring patients' completion of TB treatment is one of the crucial factors in eliminating TB and reducing the risk of developing drug resistance TB (DR-TB), which is currently a public health threat. DR-TB requires a longer course of treatment (up to three years), has more severe side effects (i.e., deafness), is more costly, and has lower success rates even with good drug adherence. In Indonesia, treatment success for DR-TB is only 52%.[3] Thus, it is crucial to ensure that all individuals with drug susceptible TB complete their treatment. However, completing the TB treatment is challenging and complex.[4,5] In 2022, the treatment success rate was 86% nationally but varied between provinces, ranging from 72% to 96%.[3]

Papua, the easternmost province of Indonesia, has a history of low treatment success rates, currently the second-lowest treatment success rate in Indonesia, and has been consistently below 75% for over a decade.[3] Aside from Papua being considered a rural area with limited resources, there is unclear evidence as to why Papua experiences higher rates of disproportionate health outcomes, including poor TB outcomes. Studies to date have focused mostly on how Papuans tend to contract TB such as living in a traditional house with insufficient ventilation and exchange of fresh air, as well as the habit of spitting indiscriminately,[6] However, few studies have explored the cause of low treatment adherence in Papua's distinct culture. Studies in Papua have highlighted factors that contribute to non-adherence, including geographical challenges or travel costs, limited patient-level TB knowledge from limited provision of TB counseling by TB nurses, lack of family support, and differences in drug administration methods.[7-9] To support TB prevention and care programs, the Directly Observed Treatment, Short-Course (DOTS) has been implemented for many years as standard care by asking family members to be treatment observers.[10] However, several studies have limited evidence of the effectiveness of family DOT in improving TB treatment adherence.[11] Currently, patient-centered care has been promoted as part of the effort to end the TB global epidemic by 2035. This method of care focuses on providing care based on the patient's needs.

A proposed solution to improve TB treatment are Digital Adherence Technologies (DATs), which are digital tools that utilize mobile phone, computer, web-based, and/or electronic sensor technology to capture detailed daily patient-specific adherence information.[12] Since 2017, when the World Health Organization (WHO) included DATs to support a patient-centered approach as conditional recommendations, they have become an alternative tool in TB care.[13-15] Various types of DATs have been tested as remote alternatives to directly observed

treatment and other standard TB care. Systematic reviews summarizing the evidence of DATs have demonstrated their feasibility and acceptability to support patient-centered care and improve treatment adherence by addressing structural barriers such as access to care, time constraints, distance to health care facilities, and cost, improving communication between patient-provider, and reducing inequity by improving outcomes among high-risk population when combined with socio-behavioral intervention.[16-23]

The implementation of DATs requires adequate information technology infrastructure, particularly internet access. According to an Indonesian national survey, in 2023, internet penetration was 78.19%, with 99.51% of users accessing the internet through smartphones.[24] In Papua, while many areas are considered rural with limited resources, internet penetration appears to be relatively high in urban centers such as Jayapura (75.89%), with most of the area in Jayapura having at least 3G mobile coverage[25] suggesting that DATs are a promising approach. A scoping review was conducted to assess the state of the science regarding digital tools to support TB prevention and care in Indonesia (see Chapter 2). In this study we identified smartphone apps related to TB, such as Sembuh TB and Empati TB, being tested in Indonesia. Few offered complete features to support treatment adherence, with most lacking an interactive component to improve patient-provider communication, which is recognized as a key feature to improve treatment outcomes. One app used Video-Observed Treatment to assure adherence but focused specifically on DR-TB patients. None incorporated a feature to accurately confirm adherence at home. Those that provided treatment adherence support primarily focused on medication reminders, with limited features for motivation and support. There was a lack of evidence that the apps were developed using human-centered design principles that draw on the

input and needs of the end-users. Notably, no app was culturally tailored to the Papua region, which has a different cultural background from other parts of Indonesia.

A DAT that includes the features lacking in the identified apps currently being evaluated in Indonesia is the Tuberculosis Treatment Support Tool (TB-TST). The TB-TST intervention includes interactive patient and provider-facing mobile applications linked with an easy-to-use, home-based direct drug metabolite test to confirm adherence remotely. The TB-TST was found to improve TB treatment outcomes (increased treatment success and lower rates of default) in a pragmatic randomized clinical trial across four public health hospitals in Argentina. Although potentially evidence-based, it was iteratively developed in Argentina for Spanish-speakers and culturally adapted with individuals with TB and TB experts. To evaluate the effectiveness of this tool in another setting and context, it will require adaptation, refinement, and testing. This study aims to culturally adapt and refine the comprehensive TB-TST intervention to the unique context of Papua with a distinct language, cultural, and setting using a human-centered design approach.

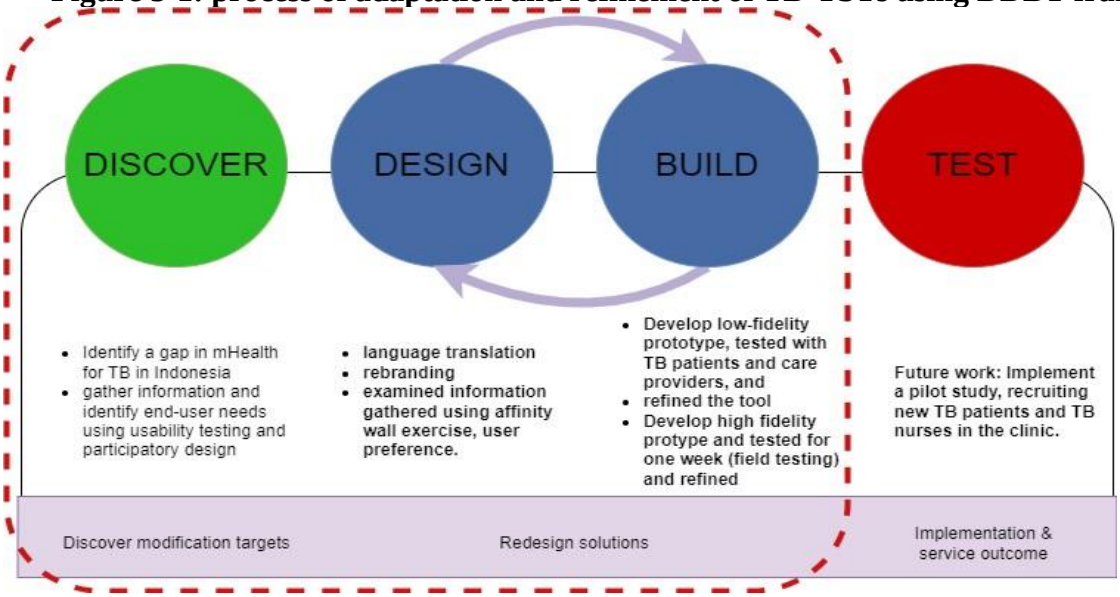
3.3 METHODS

3.3.1 Study overview

We used a multi-phase mixed method convergent design iterative process to adapt and refine the patient and treatment supporter interfaces of the TB-TST intervention for a Papua population guided by the Discover, Design, Build and Test (DDBT) framework.[26]

For this study, we focused on the first three phases (discover, design and build) to discover, develop, evaluate, and refine intervention prototypes and develop an implementation plan for pilot study (Figure 1) iteratively and systematically.

Figure 3-1: process of adaptation and refinement of TB-TSTs using DDBT framework



3.3.2 Study setting, inclusion criteria, and recruitment

This study was performed from January 2022 to July 2022 in Jayapura, Indonesia. Jayapura is the capital of Papua with a population of 400,000 and TB incidence rate of around 2,000 yearly.[27] Participants were recruited from the Voluntary Counseling Test (VCT) clinic, one of the outpatient clinics of Rumah Sakit Umum Jayapura (Jayapura Hospital) that provides care to HIV/AIDs, TB, and DR-TB patients. In 2021, the clinic treated 275 susceptible TB patients.[28] As the referral and largest hospital on the island, the clinic serves a diverse population in terms of race and ethnicity, including both Papuan and non-Papuan individuals. Patients come from across Jayapura city and the surrounding areas. Ideally, a newly diagnosed TB patient is referred to a primary healthcare center close to their home. However, many prefer to be treated at this clinic for various reasons, such as the desire to protect their privacy and easy access to hospital facilities if further treatment is needed.

Using convenience sampling, we recruited participants during their drug refill visits at the clinic. Inclusion criteria included being a Jayapura resident, at least 18 years old, being familiar with operating smartphones, being diagnosed with drug-susceptible TB, having been in treatment for more than four weeks, and being willing to complete the informed consent. Eligible participants were first approached by the TB nurses and referred to the research team if they agreed to participate. For the treatment supporter, we recruited TB nurses and healthcare providers who worked in the VCT clinic. For the technology experts, we recruited participants from Sacode (Papua's technology community group). Participants received the US equivalent of $5 compensation for their time in the refinement test phase and the US equivalent of $10 for technology experts and healthcare providers.

Institutional review board approval was obtained from the University of Washington (STUDY00014096), a recommendation to conduct research was obtained from the Provincial Unity of Nations and Politics Department in Papua, and a permit was received from Jayapura Hospital.

3.3.3 Procedures

As a first step, the app content was translated into Bahasa Indonesia, the Indonesian national language, by the principal investigator and verified by the research assistant. Both members were native Indonesian speakers and spoke English fluently. Transifex translation software[29] was used to support language translation and further translation improvements during the refinement cycles based on participant input. There was also a re-branding process that included an open competition asking the public to submit design ideas and names for the app logo that were culturally and locally adapted. A competition flyer explaining the purpose of the app re-branding was distributed through social media. We conducted a selection process of the 13 submissions by

first having the UX designer screen the designs to meet our requirements. Next, TB nurses chose the top three designs based on their preferences. Lastly, we presented the remaining design options to the hospital director for final selection. Figures 3.1 and 3.2 present the new logo and name after re-branding.

Figure 3-2: Logo and name re-branding

Samocare: Samo + care
Samo = "saya mau" (In Bahasa Indonesia with Papuan dialect) translated as: I want to, care
Care = "perduli" in Bahasa Indonesia. Translated as: Care, to care, for caring

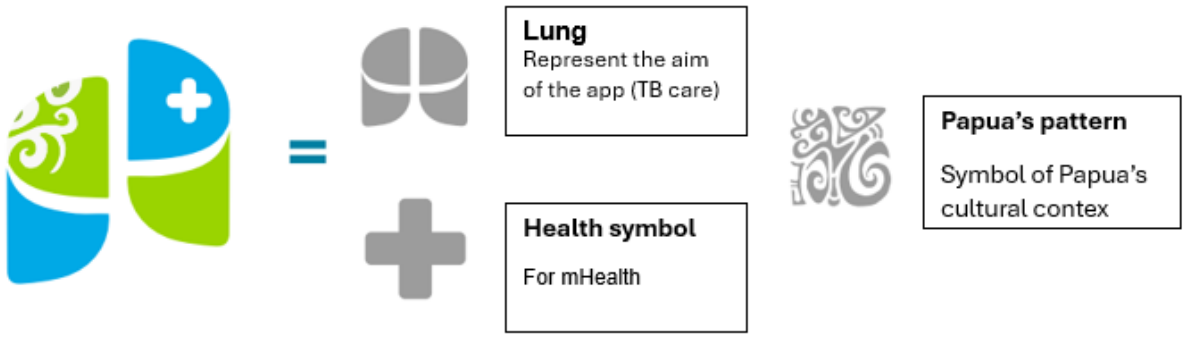
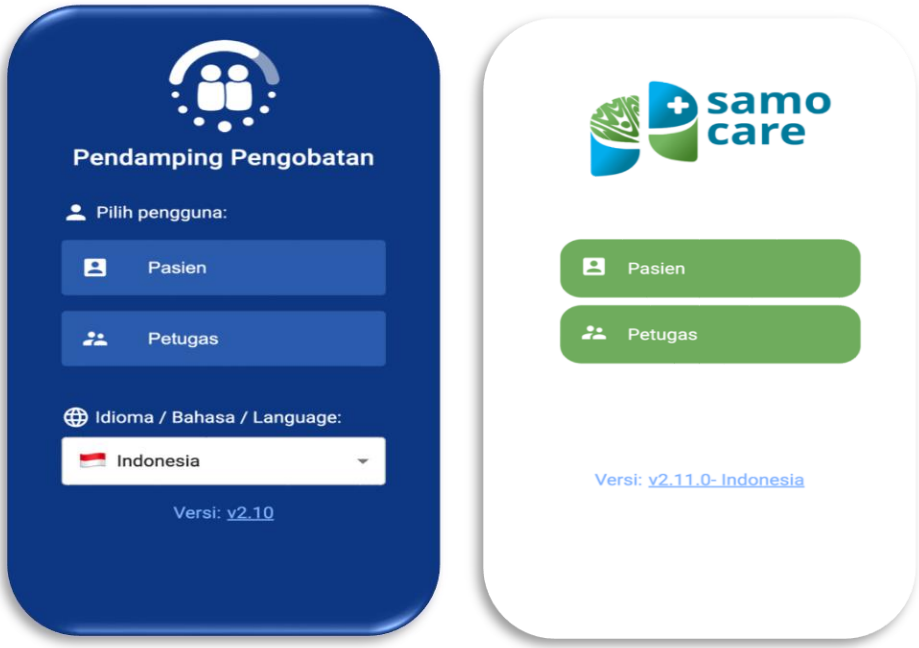


Figure 3-3: TB-TST landing page before and after re-branding.



With the translated and re-branded app, we conducted three refinement phases each for the patient (Table 3.1) and the treatment supporter interface (Table 3.2). The following details the procedures for each evaluation phase.

Table 3-1 Study activities, Goals, method, participants and duration, measurements, and outcomes for patient's interface.

	Phase 1.1		Phase 2.1	Phase 3.1
Goal	Usability testing of the translated app	Participatory design to get feedback on the app	Low-fidelity prototype usability testing of the contextually refined app	High-fidelity prototype usability testing of the contextually refined app
Methods	• Think aloud session usability test	Focus group interviews (FGD)	Usability test	Usability test
Measure	• Average time to complete task and success rate. • Observation of issues • qualitative date from interview	Qualitative date from FGD	• Numbers of participants choosing designs offered. • Qualitative data of design favor supporting reasons	• Log of issues
Participants and duration	10 patients + 5 technologists 1 time	7 providers 1-hour FGD	6 patients 1 time	8 patients + 1 providers 1 week
Outcomes	List of issues and refinement solutions.	List of refinement solution	Design preferred	• List of refinement solution • List of workflow guidelines

Table 3-2. Study activities, Goals, method, participants and duration, measurements, and outcomes for treatment supporter interface.

	Phase 1.2	Phase 2.2	Phase 3.2
Goal	Participatory design to get feedback on the translated desktop interface	Low-fidelity prototype usability testing of the translated mobile	Together with the patient interface

		interface and added features	
Methods and Measures	Focus group to understand fitness in the Indonesian context and additional features	Usability testing via think-aloud session MAUQ score and qualitative data	Log of issues
Participants	7 providers 1 hour	3 providers 1 time	1 provider each day (4 total) for 1 week
Outcomes	Discover and design: List of recommendations and requirements	List of refinement solution	• List of refinement solution • List of workflow guidelines

Phase one: The goal of this phase was to gather users' needs and preferences for app redesign. For the *patient interface*, we conducted usability testing using the think-aloud method with 10 TB patients and five technology experts in Jayapura, followed by an interview. For the usability testing, we created six tasks for the participants to complete that covered (1) submitting daily reports, (2) reporting side effects, (3) submitting a photo of a test strip, (4) reviewing the calendar, (5) setting alarms for medication reminders, (6) contacting treatment supporter. The follow-up interview questions included three broad questions: (1) What do you like about this tool? (2) What do you dislike about this tool? (3) What would you change or add to this tool?. The same questions were asked to TB nurses during FGD when we presented the patient's interface.

For the *treatment supporter interface*, we conducted a focus group discussion with seven TB nurses in the clinic by presenting the app features and functions and treatment supporter interfaces. After presenting the tool, we asked providers the same interview questions.

Measurement and analysis: For analysis, we integrated qualitative and quantitative data to interpret the results.[30] We measured the average time each participant completed the usability tasks. We observed and listed issues to group similar incidents/issues with which participants

struggled. We used rapid analysis using the affinity wall exercise (using a wall to organize large volumes of mixed information and data) to find priority issues and design solutions.[31]

Phase two: The objective of this phase was to conduct usability testing of low-fidelity prototypes informed by phase one and collect user preferences and opinions for validation.

Patient interface: We conducted usability testing on six new individuals with TB to compare the new app prototype that we created using FIGMA and the original. We asked about their preference and reasons for their design preferences.

Provider interface: We conducted usability testing of a new app prototype using the think-aloud method followed by an open-ended questionnaire and Mobile App Usability Questionnaires (MAUQ). The usability testing was focused on testing the dashboard, patient list, patient profile, and messaging features.

Measurement analysis: We conducted a descriptive quantitative analysis by quantifying which prototype the participants preferred and supporting reasons in addition to calculating the overall MAUQ score for the provider interface.

Phase three: The objective of this phase was to evaluate the refined app using real scenarios and environment to prepare for formal pilot testing. Field testing is intended to uncover issues and collect feedback on aspects that may have gone unnoticed during development, as well as to inform the mechanism of the app flow into clinical practice and develop protocols for responding to issues during pilot testing.[32] In this phase, nine individuals participated, including four TB nurses and five volunteers (two research members and three clinic's worker). Over the course of six days, the four TB nurses took turns using the app in the role of a treatment supporter, while the remaining individuals acted as patients and used the patient app. Each day, those in the patient role could select the type of patient they wanted to portray, such as one who needed

assistance or did not submit a report, or experiment with other app features like sending messages or reporting side effects. The treatment supporter was responsible for monitoring the app's activity and responding based on the submitted or not submitted reports by the participants acting as patients.

Measurement and analysis: we conducted an evaluation meeting each day for six days to discuss issues and potential strategies or design solutions to address them. We used components of Nielsen's 10 heuristic evaluation principles in analyzing data to categorize the issues identified during field testing.[33]

3.4 RESULTS

3.4.1 Demographic characteristics of participants:

The refinement phase one activities included ten individuals with TB, five local technology experts, and seven providers. The individuals with TB had an average age of 21.5 years with a standard deviation of 4.5 years, and there was an equal number of males and females. Four participants (40%) were unemployed, and three (30%) were college students. The majority (90%) used the internet daily, with seven participants (70%) spending more than four hours online daily. Their monthly internet expenditure ranged from IDR 50,000 to over IDR 200,000 (equivalent to $4-$15 USD), with 90% using prepaid phone plans. Regarding internet proficiency, five participants (50%) considered themselves functional users, while four (40%) identified as advanced users. Among the five local technology enthusiasts involved, four (80%) were male, including two freelancers, a college student, a web developer, and a university lecturer. The seven providers who participated in this phase were nurses from the clinic. Four had a bachelor's degree in nursing, and four participants were female. Of the seven providers, five had full-time work status. The refinement phase 2 involved seven individuals with TB and three

providers. Among the individuals with TB, the average age was 23.17 years (SD: 5.4). Of the seven patients who participated, three (43%) were male and four (57%) were female. Four participants were non-Papuan, while the remaining three were Papuan. Six participants (85%) had at least a pre-professional high school education. Regarding the providers, all three were male TB nurses in the clinic, with an average age of 38 years (SD: 3.3). Two of these nurses (66.7%) were on contract, while one (33.3%) held a permanent position at the hospital. The average duration of their work experience in the clinic was 4.67 years (SD: 4.7 years). The refinement phase 3 involved nine participants, with a balanced gender distribution and a slight male predominance: five participants (55.6%) were male, and four (44.4%) were female. Most participants (55.6%) were research team members and clinic workers, while the remaining four (44.4%) were TB nurses in the clinic. In terms of educational background, the participants predominantly held either a high school diploma or a bachelor's degree, with each category represented by three individuals, accounting for 33.3% of the participants in each case. Detailed information on the demographic characteristics of participants in all phases is in the Appendix Table 1.

3.4.2 Refinement result

A summary of the results from each phase based on the DDBT framework is outlined in Table 3.3. This study focused on the Discover and Design/Build activities that led to the adapted and refined intervention version tested in a pilot study (Chapter 4).

Table 3-3. Summary of findings for each refinement phase

Phase	Discover	Design and build
Phase 1 Patient interface V1: Original	- Preferred Bahasa Indonesia when asked to use local dialect.	- Improved UX design by rearranging and enlarging the buttons and icons on the homepage.

design translated to Bahasa	- The available features were all essential to the participants. - Requested feature to help motivate patient to continue treatment every day. - Improved UX design and enlarged icons.	- Revised side effect list based on Indonesia's TB guidelines. - Improved photo submission function - Improved contrast. - Add color coded explanation under calendar on the progress page. - Reorganized the information page into two categories: information about the disease and information about the app, represented with bigger icons. - Limit the group discussion. - Updated education content with materials from the Ministry of Health - Created link appointment feature in the patient's interface with the treatment supporters.
Treatment supporter interface V1 (Desktop version)	- Easy access to the tool - Simple and can support TB nurses' activity by listing patients with issues - Set a schedule for treatment supporters to monitor patients using the app.	- Created pages with lists of patients and issue filter functions based on priority (presented in icons). - Created a mobile app version. - Revised list of side effects based on Indonesia's TB guideline. - Adjusted the treatment timeline milestones on the app to fit the clinic's treatment timeline for usual care. - Added a feature for treatment supporters to set appointments.
Phase 2 Patient interface V2	- Participants accepted the changes of design except for the message page	- Transfer low-fidelity prototype to high-fidelity prototype.
Treatment supporter interface V2 (mobile optimized)	- Reiterate the need for filtered patients with issues. - Need training to learn about both interfaces before recruiting patients.	- Identified features/functions that did not work as expected. - Transfer the low-fidelity prototype to a high-fidelity prototype.
Phase 3	- Issues with different types of smartphones (create a list	- Translated remaining words that were in English or Spanish to Bahasa Indonesia - Added show/hid password.

Adapted and refined intervention	of issues as a reference for the pilot study) - A protocol for TB nurses is needed to utilize the tool daily. - Improve communication within the treatment supporter	- Fixed non-functioning features.

Phase 1:

Discover: Participants with TB accepted the translated language of the app and expressed a preference to retain the standardized language rather than transitioning to Papua's local dialect. Feedback from both patients and providers highlighted the need to improve the design by enlarging icons and reorganizing features to simplify the interface to enhance usability. While acknowledging the significance of existing features in supporting treatment, participants voiced a desire for additional features to increase motivation for treatment adherence. The TB nurses emphasized the importance of having the treatment supporter interface always readily accessible, given the demanding nature of their schedules in the clinic. They also preferred a summary view of patients requiring their attention with different symbols, enabling them to prioritize care for high-risk patients and optimize their time efficiently. To improve workflow management, nurses underscored the need to establish clear schedules and protocols for both patients and treatment supporters regarding the utilization of the app. These insights underscored the significance of refining the app design to align with the needs and preferences of users while enhancing its functionality to support effective TB treatment management.

Design and build : Usability testing with patients and participatory design sessions with nurses revealed several requirements and potential redesign solutions tailored to end-users in Papua. A recurring issue among participants was with the home page, particularly in validating actions for

submitting medication self-administration reports. Proposed solutions included implementing larger icons, rearranging buttons, and eliminating unnecessary functions deemed irrelevant for the Papua context such as online surveys. Both patients and nurses expressed consensus on the importance of adding and linking an appointment feature to both interfaces to help streamline the clinic visit and drug refill scheduling processes. Additionally, updates to the side effects list were deemed necessary to align with Indonesian TB regulations. During usability think-aloud activities, particularly when entering nausea levels, participants showed a preference for clicking icons over inputting numerical values. As a result, enhancements were made to allow participants to click icons to submit nausea levels for side effects. System improvements were also identified for the photo submission function of test strips, as participants encountered errors with camera functionality and photo uploads.

Participants found the color-coded calendar explanations confusing, primarily due to their pop-up format. To address this, the color definition key was relocated directly under the calendar for easier reference. While the messaging feature was generally clear, participants encountered difficulty locating the send button for private messages within the discussion groups. Limiting the number of groups was suggested as a solution to streamline navigation. Additionally, the information page of the original app contained a comprehensive list of information about both the app and the disease. To enhance clarity and organization, this section was reorganized into separate sections for information about the disease and information about the app. Participants requested improved color contrast to enhance readability and accessibility.

In response to participant feedback requesting additional features to support motivation to remain adherent to treatment, a behavioral motivation feature was developed. This feature changed daily

to provide ongoing support and celebrate patient progress/milestone throughout their treatment journey.

Five key themes from focus group discussions led to significant refinements of the desktop version of the treatment support interface. First, a dedicated page was added to list patients with issues and prioritize tasks, enhancing work efficiency. Second, a low-fidelity mobile prototype was developed for greater flexibility, allowing treatment supporters to monitor patients via smartphones. Third, the list of side effects was corrected to align with Indonesia's TB regulations. Fourth, the treatment timeline was synchronized with the clinic's biweekly drug refill practice, and a set appointment feature was added, linking to the patient's app.

Phase 2:

Discover: For the patient interface, when participants were asked to compare the old and new prototypes informed by the first phase refinement, design preferences favored the updated versions. Specifically, 64% of participants favored the new prototype of the home page, 83% preferred the new prototype for the progress page, and all participants agreed with the new prototype that grouped TB information into two categories. For the message page, an equal number of participants chose the old and new versions, although their comments suggested a slight preference for the old version. Participants favored the mobile version for the treatment supporter interface, as indicated by an overall Mean Average Usefulness Questionnaire (MAUQ) score of 138 (SD 7.8) out of a maximum score of 147. Upon closer examination of MAUQ scores, the average ratings for usability and ease of use, system information, and perceived usefulness were 52.33 (SD: 10.33), 38.33 (SD: 3.2), and 47.3 (SD: 1.5), respectively, indicating high usability overall. Despite the high average MAUQ score, observations during usability testing revealed that participants encountered difficulties and spent significant time navigating

certain features within the tool. Participants acknowledged the need for time to familiarize themselves with both the provider and patient interfaces to effectively teach patients how to use the tool. To address this challenge, a one-day training session was scheduled for TB nurses a day before field testing, enabling them to learn all features and functions of both interfaces and practice registering new patients, thereby enhancing their proficiency with the tool.

Design and build: based on the design preference result, the low-fidelity prototypes were integrated into the functional app (see Figure 3.4, 3.5, and 3.6) to reflect the preferences and feedback of the participants. We fixed the app functions that did not work properly for the treatment supporter interface. The low-fidelity mobile app prototype was transferred into the functional app (Figure 3.7) to reflect the improvements and address the identified issues.

Figure 3-4: Prototype for the home page: before usability testing, low-fidelity prototype informed by phase 1, and final version for pilot study.

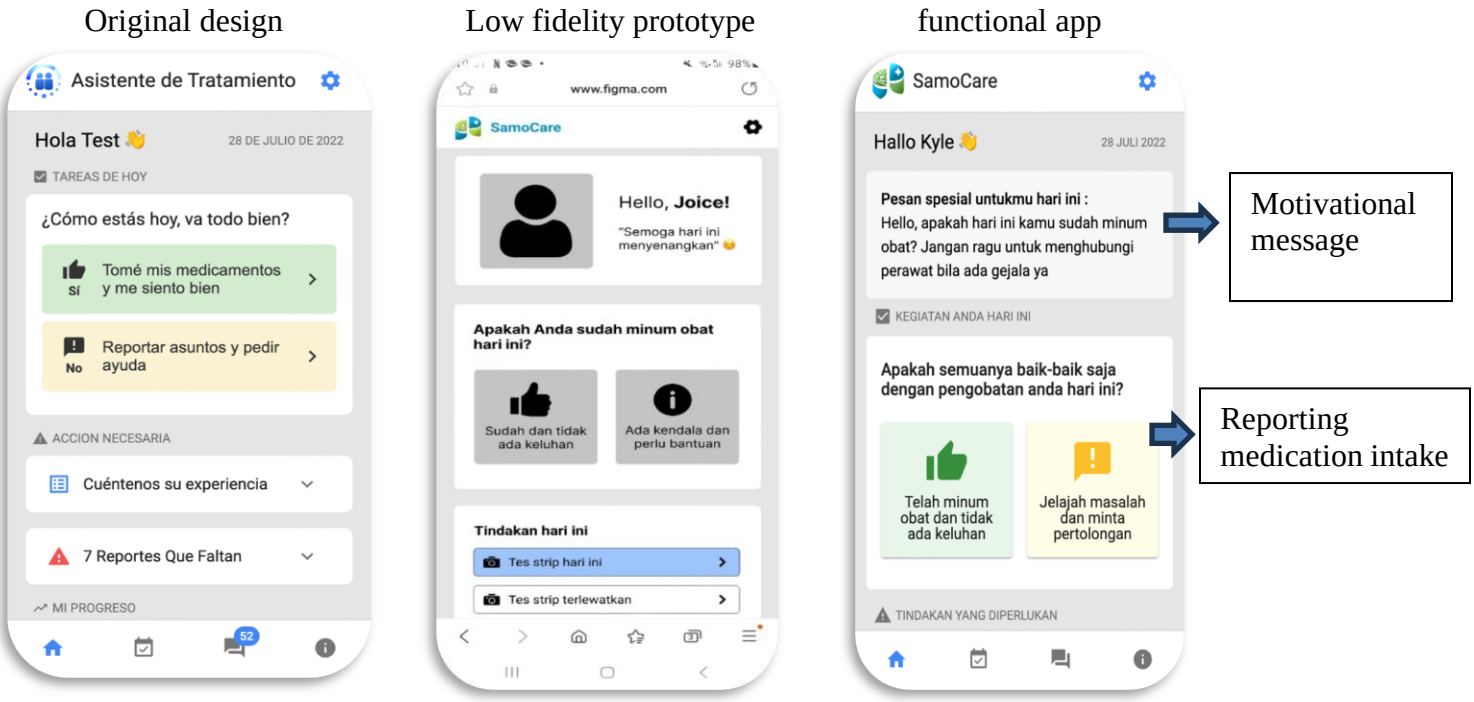


Figure 3-5: Prototype for the home page: before usability testing, low-fidelity prototype created informed by phase 1 and the final version for pilot study.

Original design | Low fidelity prototype | Functional app

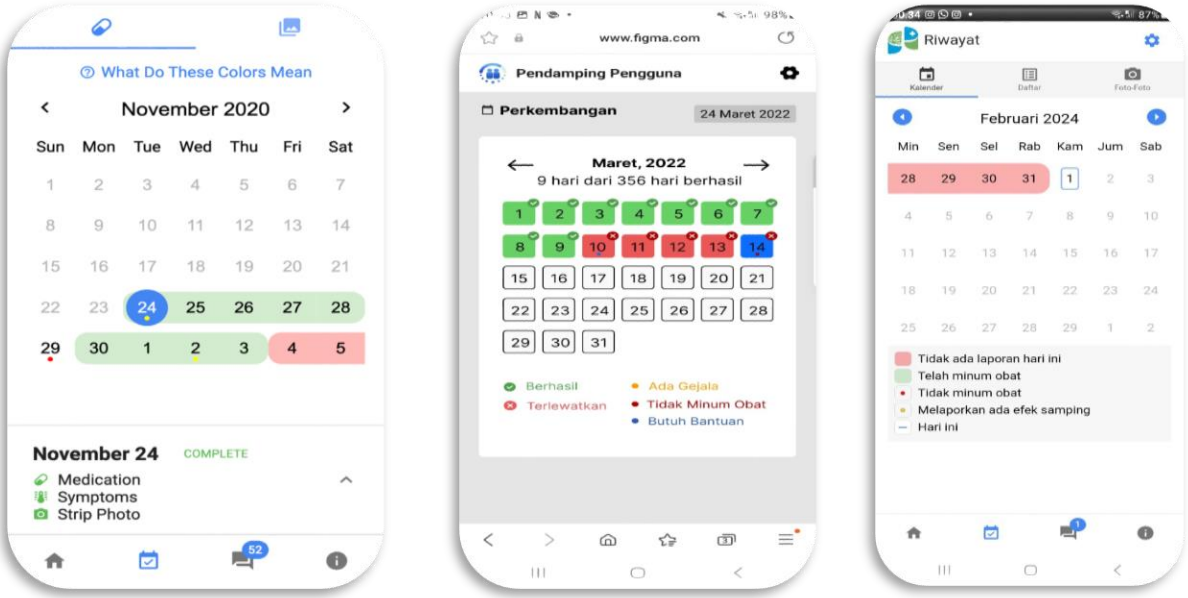


Figure 3-6: Prototype for information: before usability testing, low-fidelity prototype created inform by phase 1, and final version for pilot study

Original design | Low fidelity prototype | Functional app

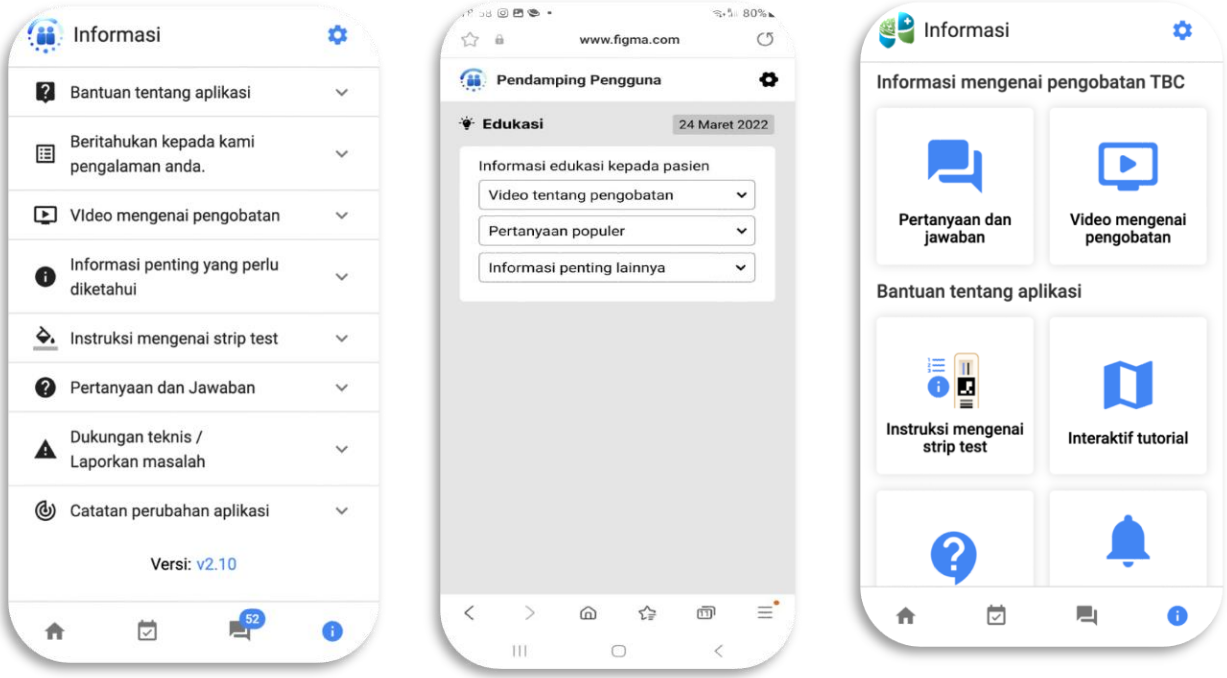
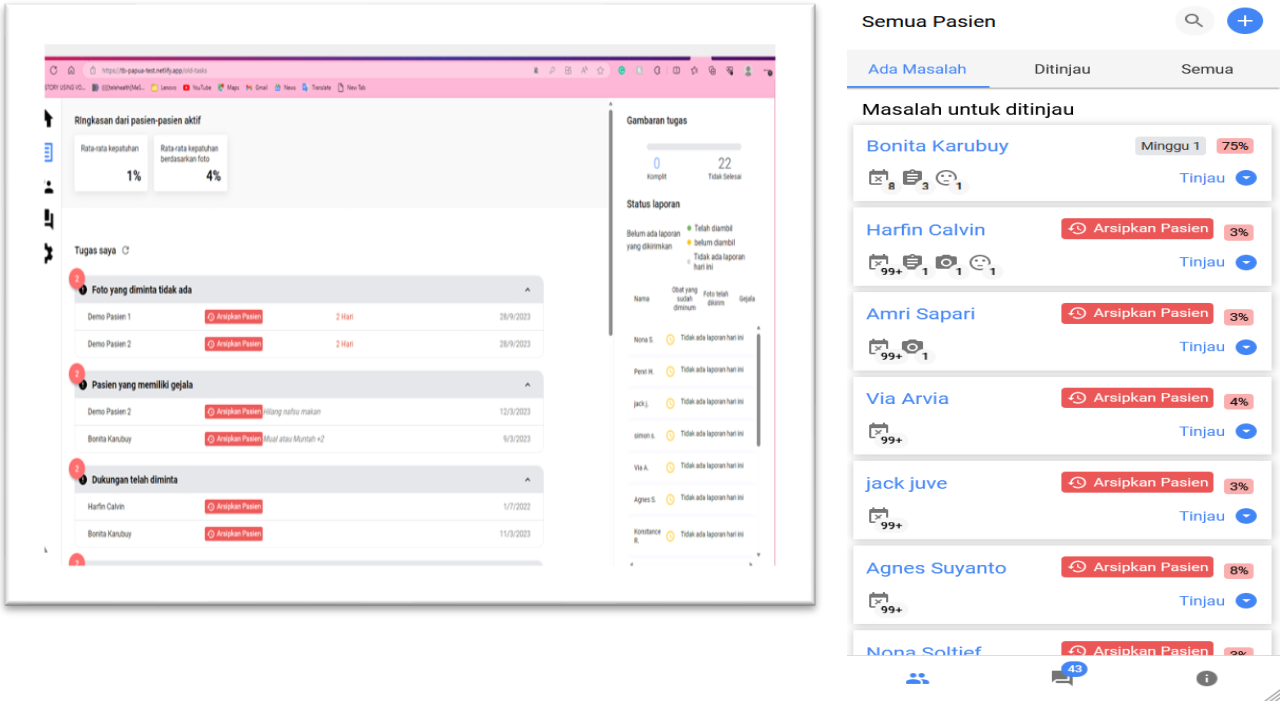


Figure 3-7: Provider interface refinement from desktop to optional mobile app version

Desktop version (original design) Mobile app version



Phase 3:

Discover: Several unexpected issues were identified during the installation of the app to the screen phone that were attributed to differences in smartphone types/brands. For example, phone type dictated the location of menu settings within the phone's interface, such as location settings and push notification activation. To address this variability, a comprehensive list of issues, categorized by phone type/brand, was created as a reference for future use during the pilot study. In the daily evaluation discussions during field testing, the need to establish a protocol for patients and TB nurses to utilize the tool daily was recognized. TB nurses also expressed the need for a mechanism to ensure seamless coordination among team members in monitoring patients' tool usage and passing along important patient information to the next nurse in charge to

prevent details from being overlooked in patient care. To address these needs, a schedule and protocol for monitoring patients using the tool were collaboratively developed. To facilitate app technical issues, a communication channel using WhatsApp was established to enable treatment supporters to communicate directly with the principal investigator or research assistant and receive prompt responses to address technical issues that might arise during the pilot study. This multi-faceted approach aimed to enhance the efficiency and effectiveness of utilizing the tool in patient care management.

Design and test: Throughout the testing period, it was observed that several words had not been translated into Bahasa Indonesia. As a result, an iterative translation process was undertaken to ensure completeness. Furthermore, as TB nurses took turns acting as treatment supporters each day, some encountered difficulties when logging into the app because they were unable to see the password they had typed. To address this issue, a "show or hide password" feature was added to facilitate login, while efforts to fix remaining features, such as the notes function, that could not be accessed were continued.

3.5 DISCUSSION

This study aimed to iteratively adapt and refine the TB-TST intervention for a Papuan population and setting using a human-centered design approach to improve TB care and treatment outcomes. The intervention was successfully re-branded during the preparation phase. By involving TB patients, care providers, and design experts during the iterative refinement phases, we successfully culturally adapted and refined both app interfaces. The iterative refinement process resulted in adding several changes and new features, including a daily motivational behavior-change message on the patient homepage, correction of side effects, a new appointment

scheduling feature for the treatment supporter dashboard linked to the patient's app, and improved UX design and color contrast. The final stage of field testing resulted in an understanding of the mechanism and flow of app usage to anticipate issues that might be encountered in the pilot study, in addition to a protocol for monitoring the app.

Several factors contributed to the success of the adaptation and refinement of the tool. First, our findings underscore the importance of partnering with end users to improve functionality and ensure relevance, user-friendliness, and alignment with user expectations. Through several phases of rapid iteration, we were able to focus on the function and feature that end users needed. It also provided an opportunity for treatment supporters to understand the flow of the app better, figure out ways to maximize the tool and keep user engagement, and develop protocols in preparation for pilot testing. Understanding user preferences, such as the technology they use and their engagement patterns, is crucial for ensuring the app's smooth implementation and its potential to improve healthcare services for individuals.[19,34-36] One study assessing the critical success factors for mHealth implementation in Indonesia emphasized the importance of engaging specific groups in app development to understand and cater to their unique needs.[37]

Second, Papua's geographic location as the easternmost province of Indonesia makes it significantly remote from the country's central regions, leading to its status as one of the least developed areas. Consequently, health programs in Indonesia, which are often initiated and tested in urban and central regions by the Ministry of Health, may not fully address the unique needs of Papua's diverse cultural and ethnic composition of both indigenous and migrant populations. This disparity underscores the need for a tailored approach to interventions to ensure cultural relevance and context appropriateness for the Papua community, especially in the context of TB, for which personalized patient-centered care is needed to reduce inequity.[22] To

our knowledge, this is the first study conducted in Papua that has engaged healthcare providers, patients, and design experts in rigorous iterative refinement phases for DAT. This close involvement, which is the essence of participatory design, prioritizes mutual knowledge and understanding and fosters a sense of belonging and care [38] that resonates with the Papuan community and culture. In the future, Papuans may have higher confidence in the app if they are informed that its development involved the input of Papuans. Third, we believed that tailoring the app's language to fit the local dialects would improve its usability, considering Papua's unique dialect, which is different from standard Bahasa Indonesia. However, after involving end users, we discovered a preference for the use of standard Bahasa Indonesia. Deferring to this newly discovered preference helped align the app with principles of inclusivity since this preference reflects the participants' acknowledgment of Jayapura as a melting pot of cultures and traditions, whereas Bahasa Indonesia is preferred as a lingua franca that can connect different ethnic groups. This finding was a pivotal example of the importance of implementing a human-centered design approach to improve app usability and accessibility across the diverse Papuan population.

Finally, this study serves as a trailblazer in providing valuable information that will be instrumental for future health transformations in Papua. It provides an example of a tailored health intervention in Papua. Future studies are needed to determine the feasibility, acceptability, and impact of the tool in improving TB treatment adherence and outcomes.

3.6 LIMITATION

Although this study has many strengths, there are several limitations to consider. First, despite participants coming from different geographic locations to be attended to at the reference hospital where the study took place, it is in an urbanized and modern area of Papua where a

significant portion of the population has access to the internet and own smartphones. This setting is not representative of all areas in Papua, with limited or no internet access and varying levels of digital literacy. Additionally, the use of a convenience sampling technique for recruiting end users may limit the generalizability of our findings. Participants were approached on a rolling basis as they returned to follow-up appointments or medication refills, and this may or may not reflect a broad representation of the various populations. Future research should be conducted to identify insights from a broader context within different Papua regions.

3.7 CONCLUSION

We have adapted and refined the TB-TST intervention, re-branding it as Samocare to align with Papua's community's cultural and contextual unique needs using multiple iterative refinement cycles and testing processes guided by the DDBT framework. The Samocare DAT intervention was readied, and the TB nurses trained in preparation for the next phase of pilot testing among individuals newly diagnosed with TB for the full 6-month course of treatment. This upcoming study aims to assess the feasibility and acceptability of the adapted and refined DAT in a real-world setting.

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Multimedia Appendix 3-1. Demographic characteristics of participants in each phase (1-3)

Variable		
Demographic of Individuals with TB phase 1, n=10		
Age, mean (SD)	21.6	4.5
Sex, n (%)		
Male	5	50
Female	5	50
Employment, n (%)		
College student	3	30
Private sector	2	20
Unemployment	4	40
Housewife	1	10
Weekly internet usage, n (%)		
1-2 days	0	0
3-4 days	1	10
5-6 days	0	0
Everyday	9	90
Daily internet usage, n (%)		
< 1 hour	0	0
1-2 hours	2	20
3-4 hours	1	10
> 4 hours	7	70
Money spent for internet each month, n (%)		
< Rp. 50.000,-	1	10
Rp. 50.000,- to Rp. 100.000,-	40	40
Rp. 110.000,- to Rp. 200.000,-	10	10
> Rp. 210.000,-	40	40
Type of provider, n (%)		
Pre-paid phone plan	9	90
Post paid phone plan	1	10
Internet skill, n (%)		
Expert User	0	0
Advance User	4	40
Functional User	5	50
Knows About	1	10
None	0	0
The demographic of design expert phase 1, n=5		
Age, Mean (SD)		
Sex, n (%)		
Male	4	80

Female	1	20
Occupation, n (%)		
College student	1	20
Freelance	2	40
Web developer	1	20
University lecturer	1	20
The demographic of provider refinement phase 1, n=7		
Age, Mean (SD)	46	9.7
Sex, n (%)		
Male	3	42.9
Female	4	51.7
Level of Education, n (%)		
Pre-professional high school	1	14.3
Associate's degree	2	28.6
Bachelor's degree	3	42.9
Master's degree	1	14.3
Race, n (%)		
Papuan	3	42.9
Non-Papuan	4	57.1
Work status, n (%)		
Full-time	5	71.4
Temporary	2	28.6
Demographic of Individuals with TB phase 2, n=7		
Age, Mean (SD)	23.17	5.4
Sex, n (%)		
Male	3	42.9
Female	4	57.7
Level of Education, n (%)		
Pre-professional High school	1	14.3
Associate's degree	2	28.6
Bachelor's degree	3	42.9
Master's degree	1	14.3
Race, n (%)		
Papua	3	42.9
Non-Papua	4	57.1
Working status, n (%)		
Full-time	5	71.4
Temporary	2	28.6
Demographic of providers refinement phase 2, n=3		
Age, mean (SD)	38	33
Sex		

Male	3	100
Female	0	0
Working status		
Full-time	1	33.3
Temporary	2	66.7
Years working in the clinic, mean (SD)	4.67	4.7
MAU, mean (SD)	138	7.8
Usability ease of use, Mean (SD)	52.33	10.33
System Information	38.33	3.2
Usefulness	47.3	1.52
Demographic of participants refinement phase 3, n=9		
Age, mean (SD)	39.11	6.13
Sex, n (%)		
Male	5	55.6
Female	4	44.4
Level of Education, n (%)		
High school	3	33.3
Vocational degree	1	11.1
Bachelor's degree	3	33.3
Master's degree	2	22.2
Status, n (%)		
TB Nurses	4	44.4
Volunteers	5	55.6

Multimedia Appendix 3-2. Data analysis for refinement phase 1 patient interface , N=15

Design Focus	Sources of data	Data	Redesign recommendation
Home page	Usability task and observation: Submitting daily report	Average task completion time: 1.18 minutes	Improve UX design by rearranging and enlarging the buttons and icons.
		10 participants who completed the report submission did so in more than 1 minute or was not certain if they had successfully submitted the report.	
		Opened other features such as appointment.	
		"Because this is the core component, we should make it bigger" (P11).	

	Usability task and observation: Reporting side effects	5 participants could not locate the edit icon and reported it was too small.	Improve UX design by rearranging the side effects list, improving contrast (line) to separate the list of side effects and modify the nausea level.
		4 participants clicked the icon for pain rather than adding numbers.	
		Average task completion time: 2.62 minutes.	
		7 participants made some errors.	
		"The list was too cramped. It is better to have separate boxes" (P10).	
	Usability task and observation: Submitting a photo test strip	7 participants (early test) experienced error in opening their camera apps.	● Make a clear instruction for the test strip ● Improve the system
		Participants asked for instruction.	
		Average task completion time: 0.8 minutes.	
		Four participants made errors.	
	Usability task and observation: Setting alarm for med reminder	Average time of completion: 1 minute.	Improve the UX design, using 24 hours style.
		Error: 1	
		3 participants had a hard time locating the alarm function and confirming alarm set up.	
Progress page	Usability task and observation: Review calendar	Average task completion time: 2.13 minutes.	● Put the color explanation under the calendar.
		Not all participants could explain the colors on the calendar, and 9 participants could not find the pop-up texts explaining color.	● Remove some unnecessary information.
Messaging page	Usability task and observation: Contact treatment supporters	6 participants confused it with appointment.	● Set up the system where only provider can create group and discussed with providers what kind on topics group we can put before launching. ● Allow users to change the size of the font.
		Average task completion time: 1.34 minutes.	
		Error: 4	

Information page	Interview with participants and participatory design with TB nurses	*"So, it's better have a group of information about the app and then a different group about the disease" (P3).* *"We have a lot of education materials for TB… let me see from the Ministry of Health" (Nurse 1).*	● Create two group of information: about the TB and about the app. ● Update education content. Use the materials from the Ministry of Health as sources.
Appointment	Interview with participants and participatory design with TB nurses	*"Appointment reminders should be set up by healthcare providers" (P13).*	Link the appointment feature with the provider's side and create feature where providers can set appointments for patients.
Aesthetics: language, colors, graphics/pictures	Interview with participants	*"Overall good. If it's possible, make the text smaller, bigger and brighter" (P6).*	● Improve color contrast. ● Improve language translation.
Additional	Interview with participants	*"Maybe something like sticker to motivate patients to continue the treatment" (P3).* *"We need statements that can motivate us" (P6).*	Add daily motivational behavior-change quotes.

Multimedia Appendix 3-3. Phase one refinement for treatment supporter interface: Theme, exemplar quotes, and refinement solutions

Theme	Problem	Representative quotes	Design solution
Priority task/tailoring patients with issues	The dashboard only has a list of participants and a list of tasks to do, categorized by issues, not by patients	● *"For me…. Let say we have 8 patients, so on the home page… we can see the list of patients from 1 to 8… If the patients have reported and there are no issues, then we do not need to put anything on their name… but if the patient reports some issues or does not submit today's report… by the patient's name we should see a sign or notification like… an exclamation mark (!) or something…. For those who report side effects, or does not send a test strip photo, or need immediate help, we can see from the exclamation mark sign" (N4).*	Create a page with list of patients and the issues… and filter based on priority (patients with low adherence or other issues)

		• *"So, the first thing we open should be the page with list of patients… then if there is a warning, we can click on the name and go to the next page with these four elements… then we'll know the detailed issues" (N1).*	
Work flexibility	The current tool for the provider interface is still dashboard -based.	• *"Mmm…. If we bring it home… it's a lot of hassle" (N1).* • *"That's right…. I mean… the patient can report anytime, right? If they have a problem.. they report it right away" (N2).* • *"What I mean… you have the app… I have the app…. I can monitor the patients from my phone... while I am scrolling my phone… I can also take a look if the patients have issues" (N4).*	Create mobile app version
Side effect	There were several side effects that were not common	• *Tingling maybe less_(N3).* • *"The bone pain is from pyrazinamide, tingling is from isoniazid. That's the side effects frequently reported…. But blurry vision… maybe from ethambutol… but it's very rare. The most common are tingling… joint pain usually happen in the early stage. Swollen face maybe not…. Usually happens in legs or feet. Swollen faces occur when the person use corticosteroid… which is probably rare" (N1).*	Need to revise side effects list based on Indonesia's TB guideline
Timeline / Treatment milestone	Clinic has a different timeline	• *"Clinic visit or drug refill visit is usually twice a month… that's the standard… if we are talking about DOTS" (N3).* • *"The regulation now only has two categories… drug-susceptible TB and drug resistance TB. For drug susceptible TB, if the sputum test result is not being converted after the intensive phase, then we need to do another rapid molecular test for testing drug resistance" (N1).*	Adjust timeline to clinic usual care and TB guideline. Add to the milestone or make notes to educate patient.
Effective workflow / minimizing	The providers never	• *Let's create a schedule (N1).*	Set schedules for the providers to take turns in

barriers in using the app	integrated an app to support their work, thus needing to prepare and set the environment	● *"Oh… So there should be a rule for the patients… you have to report at least before this hour" (N2.)*	monitoring patients using the app in addition to rules for the patients.

Multimedia Appendix 3-4. Refinement phase 2 for patient interface: patients' design preference and reasons

Design focus	Preference		Support statement
	Original	New prototype	
Home page	33%	64%	*"This one makes the home page seem bigger and clearer" (P3).*
Progress page	17%	83%	*"This one is awesome… I don't need to click other things to figure out the color's meaning" (P4).*
Message page	50%	50%	*"I don't see any problem" (P5).*
Information page	0%	100%	*"Grouping into similar categories makes it less confusing" (P3).*

Multimedia Appendix 3-5. Refinement phase 2 for provider interface: data analysis from think-aloud usability testing

Usability task	N	time to complete	supporting statement/observation	Possible solution
Contact the patient about their report to see how you can help and remember to complete the task.	N1	3.14	*"I feel confused."*	● Create a page with a list of patients filtered by priority issues. ● Fix the add note function error.
	N2	0.49		
	N3	2.12	*"I'm confused because there are too many repetitions."*	
Make a note on his file from your contact discussion.	N1	0.53	*"Add note function did not work."*	
	N2	0.22		
	N3	1.32		
Work to verify and process 'Test Papua 5' test strip image.	N1	0.49		
	N2	0.54	*"I still get confused… too many tasks."*	
	N3	0.56		

View Test Papua 6's profile and find their last report.	N1	0.17		
	N2	0.44	*"So, after this, what should we do?"*	
	N3	1.23	click milestone	
Identify your patients who are having difficulties and are in high priority.	N1	1.1		The nurses/treatment supporters need training to use the tool before recruiting patients for pilot study.
	N2	0.47		
	N3	1.36	*"So, what should we click if we want to see lab test result?"*	
Identify the patient with the lowest level of adherence and check their number of missed reports this month.	N1	0.52		
	N2	0.17		
	N3	0.41		
Add the new patient, Test Papua 18, to your cohort.	N1	0.49		
	N2	0.54		
	N3	1.08		
Check how many sputum tests that Test Papua 5 completed.	N1	1.03	looked confused	The nurses/treatment supporter need training to use the tool before recruiting patients for pilot study
	N2	1.02	clicking another feature	
	N*3	1.46	*"Well, just ask the patient, right?"*	
Check to see how often Test Papua 6 reported taking medication this month.	N1	0.39		
	N2	0.41		
	N3	55.4		
Identify the most common symptom in your patient.	N1	0.27		
	N2	0.25		
	N3	0.36		
Reset the password for Test Papua 6.	N1	0.45	click setting	
	N2	1.09		
	N3	0.39		
Remove a patient message that was posted on the 5th of December in the general discussion group chat.	N1	1.48		The nurses/treatment supporters need training to use the tool before recruiting patients for pilot study
	N2	1.13	*"So, should I click this one?"*	
	N3	0.55		

Note: * did not finish the task.

Multimedia Appendix 3-6 Refinement phase 3 for both interfaces. Thematic analysis based on elements of 10 heuristics evaluation.

Heuristic element	**Definition and data**	**Desing Solution**
Consistency and standards	**User should not have to wonder whether different words, situation, or actions mean the same thing. Follow platform conventions.**	List issues with different types of smartphones to use as a guideline when recruiting participants for the pilot study.
	Each type of smartphone has different settings to pin the web app to the screen (observation).	
	Problems with end users who use dark mode on their smartphones.	
	Different types of smartphones have different locations for settings and different ways to activate push notification (observation).	
Match between system and real world	**The design should speak the users' language. Use words, phrases, and concepts familiar to the users, rather than internal jargons.**	Translate all remaining words that are still in Spanish to Bahasa Indonesia.
	"Push notifications are still in Spanish: "So… during the process, we will encounter problems… but at least this Saturday all the Argentinian language should be translated to Indonesian!" (N4).	
Error Prevention	**Good error messages are important, but the best design prevents problems from occurring in the first place.**	Create a communication channel (WhatsApp group) that includes treatment supporters and PI for fast response when issues arise.
	"So… look at this… if I try to play with all the features and make a mistake—for example, if I accidently archive a patient—how do I undo what I've done?" (N2).	
	"When I re-login as a treatment supporter, I have trouble entering my password" (N2).	Add show/hide password function
Flexibility and efficiency of use	**Shortcuts that are hidden from novice users may speed up the interaction for expert users.**	Set a protocol for monitoring patients and maintaining patient engagement
	"Then, Ma'am, in this review, if we check it like this, it will immediately disappear, right?" (N2).	
	"Until when can a patient reply to the message? What if he/she does not reply to it for so long?" (N4)	

	"For instance, if they can't make it, they won't appear in this. For example, if for this week's task they suddenly don't show up, you must immediately inform us all, 'These people didn't show up today: person A, person B, person C,' like that. Then you've already contacted them, right? We're not responsible because you have the responsibility; you first contact them, if they can't be reached, then you contact the second person, right? Contact the second person, get their phone number, once you get the phone number of the second person, then it's settled. But if the first contact can't be reached, and the second one can't, immediately arrange a home visit. We mustn't wait for up to a week" (N1).	
Help and Documentation	**It's best if the design doesn't need any additional explanation. However, it may be necessary to provide documentation to help users understand how to complete their task.**	Set rules or protocols for monitoring TB flow for treatment supporters and reporting for patients.
	"Every 2 weeks, 2 weeks responsibility" (N1).	
	"We should set the rules for patients to submit the report at 11 AM the latest" (N3)	
	"So, for our strategy to remind them as well, we ask for two phone numbers. Now, the first phone number is from the family as a backup in case we can't contact the patient, perhaps due to issues with their own phone that we discovered yesterday. There were problems with the data, but we can confirm with the second person, the family" (N1).	

Chapter 4. FEASIBILITY AND ACCEPTABILITY OF AN INTERACTIVE DIGITAL ADHERENCE TECHNOLOGY (SAMOCARE APP) FOR PATIENTS WITH ACTIVE TUBERCULOSIS IN PAPUA, INDONESIA: SINGLE-ARM PROSPECTIVE PILOT STUDY

4.1 ABSTRACT

Background: Papua, the easternmost province of Indonesia, has reported low treatment success rate for decades. One proposed tool to improve treatment success rates is the Tuberculosis Treatment Support Tools (TB-TST) that links an interactive mobile application for patients and providers with a home-based direct drug metabolite urine test to confirm adherence remotely. The tool was adapted and rebranded as the Samocare app for Papua, Indonesia context and populations. In this study, we aimed to determine the usability, feasibility, acceptability, and initial impact of the Samocare intervention on TB care in Papua and identify areas for future improvement.

Methods: We conducted a prospective, single-arm, pilot study of the Samocare intervention with 20 individuals newly diagnosed with drug-susceptible TB at a public health hospital in Jayapura, Papua-Indonesia. Participants were assisted in installing the app on their mobile phone and asked to report their medication intake daily for the full course of treatment (six months). Five clinic TB nurses served as treatment supporters using the provider dashboard to monitor the participants. We collected data from baseline questionnaires, mHealth app usability questionnaire (MAUQ), app logs, exit survey and interviews. Outcomes were usability, feasibility, and acceptability. Treatment outcomes were assessed to measure the initial impact of the intervention compared to historic treatment success rates.

Result: The average daily self-reported adherence through the app was 62% (range; 24%-100%) and the average percentage of test strip photo submission is 30% (range; 0%-83%). Sixteen (80%) successfully finished the six months treatment, three died, and one was lost to follow-up. MAUQ scores were high at two time points (8 weeks and 24 weeks). Average ratings for the app and test strip ease-of-use and whether they would recommend the intervention for others was 3.9, 4, and 3.9 out of 5, respectively. From the interview with 16 patients and four treatment supporters, we identified four main themes: perceptions about the app, experiences of using the app, challenges in using the app, and recommendations and future expectations.

Conclusion: Findings suggested that the Samocare intervention was feasible, acceptable, and perceived to be useful. Patients and treatment supporters reported that the app facilitated patient-centered care by improving communication and tailored support. Randomized controlled trials and implementation research are needed to evaluate the effectiveness of this intervention on supporting TB programs to improve treatment outcomes, particularly among Papuans and within limited resources setting.

4.2 INTRODUCTION

Tuberculosis (TB) is preventable and curable. However, in 2022 TB was the second leading cause of death from single infectious agent after coronavirus disease (COVID-19).[1] According to the report, the total number of people newly diagnosed with TB in 2022 was 7.5 million, marking the highest number since World Health Organization (WHO) began global TB monitoring in 1995.[1] In alignment with the WHO targets to eliminate TB by 2030, Indonesia has committed to securing the highest-level government support through Presidential Decree No. 67 in 2021, which requests all governmental sectors to assign TB as a priority program and allocate

budgetary support for the elimination efforts in each regional local spending.[2] Despite progress made in the last two decades, the data shows that in 2022 Indonesia contributes 10% of TB cases worldwide and approximately 1.06 million people have active TB making Indonesia the second country with the highest TB burden, following India.[1]

Treatment adherence is a crucial part of eliminating TB. Patients who do not complete their full six-to-nine-month course of anti-tuberculosis treatment have a higher risk of morbidity and mortality and developing TB drug resistance.[3,4] A four-year cascade care analysis of management of TB drug resistance in Indonesia indicated that for those with history of TB treatment, 11.3% of those lost to follow up during drug susceptible TB treatment contributed to rifampicin resistance TB drug (RR-TB) case.[5] To improve TB treatment care, Indonesia has used a Directly Observed Therapy (DOT) strategy to promote treatment adherence by requesting a family member to be the treatment observer for the patient.[6] There have been mixed results for DOT by family members with one study finding no significant improvement in treatment adherence compared to when self-administered. [7] Currently, Indonesia maintains an 83% treatment success rate nationally, well below the WHO target of 90%.[8] Several factors associated with nonadherence to TB treatment in Indonesia have been identified, including the national TB system (public-private mix data inconsistency), financial burden, gender (male), low TB literacy, stigma and cultural belief, limited access to health facilities, and lack of social support.[9-15]

When reviewing TB treatment success rates by province, considerable variation exists. Papua, the easternmost province in Indonesia, has consistently reported low TB treatment success rates for decades, ranging from 72%- 77%, making it the province with the second-lowest rate in the country.[8] Systematic reviews have reported that indigenous peoples worldwide generally have a higher prevalence of several social and proximate determinants of TB, such as

alcohol use, overcrowding, diabetes, substance misuse, HIV, food insecurity, and smoking habits.[16-18] However, with the lack of evidence, it is poorly understood why Papua continuously reports low rates of TB treatment success. Limited studies have identified factors associated with non-adherence in Papua, such as poor access to healthcare services due to geographical challenges or travel costs, limited patient-level TB knowledge from a limited provision of TB counseling by TB nurses, lack of family support, and drug regimen type (fixed or combined drugs vs individual drugs with higher pill burden).[19-22]

An alternative strategy to improve TB adherence is through the use of digital adherence technologies (DATs) defined as tools that utilize mobile phone, computer, web-based and/or electronic sensor technology to support the capture of detailed, daily, patient-specific adherence information.[23] In 2019, WHO recommended incorporating digital mHealth globally to improve systems functioning and patient outcomes[24] and highlighted the importance of incorporating technology for TB treatment care and support in the most recent WHO operational handbook on TB.[25] One of the DATs that has been widely used to support TB treatment is the Mobile Health application (mHealth app). The mHealth app emerged as one of the best strategies to mitigate treatment disruption caused by COVID-19.[26-28] Although the long term impact of mHealth apps on TB treatment is mixed, they have shown potential benefits for treatment adherence.[29] While in Indonesia several mHealth apps have been available to support TB treatment, none were identified that have been tailored to meet the unique needs of the Papua population.

Despite numerous efforts to enhance the TB treatment success rates in Papua, there has been limited focus on leveraging technology. Although much of Papua is rural, Jayapura City, the fastest-growing urban city in the province, has the highest internet penetration on the island. In 2023 alone, the internet penetration percentage was 75.89% compared to 78.19% nationally.[30]

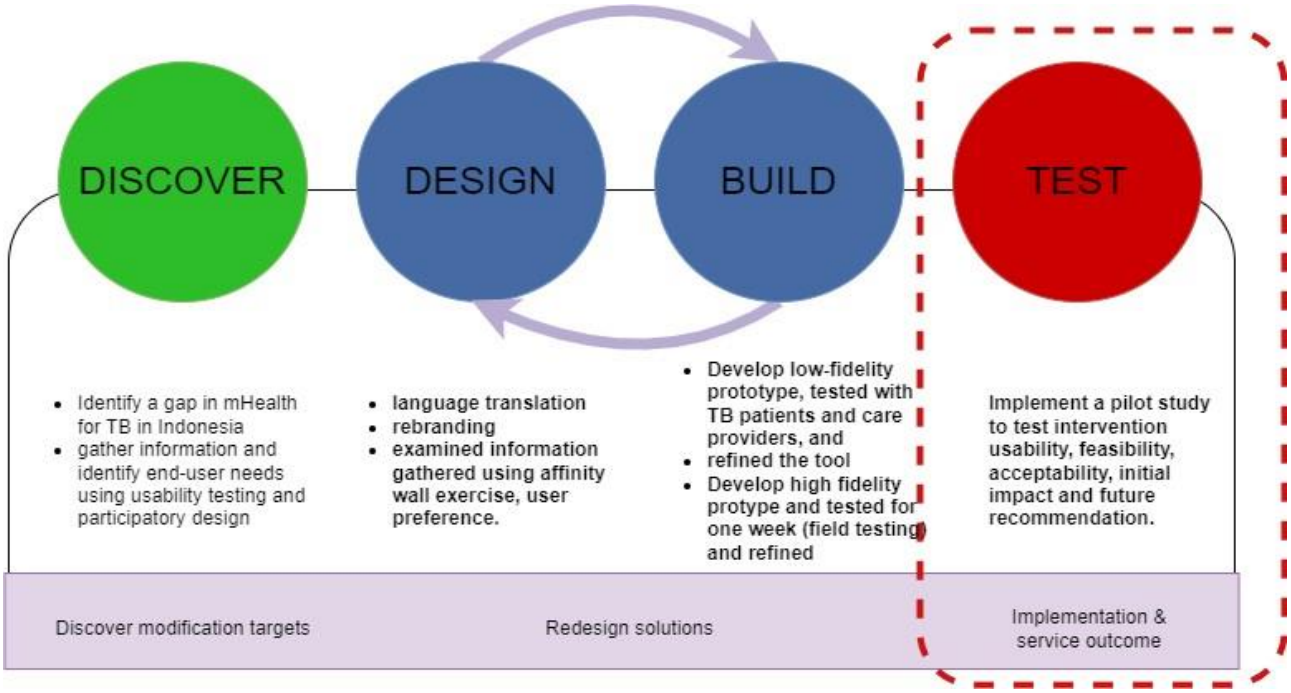
Most of the area can access 3G cellular phone network.[31] In addition, Jayapura, the most populated city in the province, consistently records the highest number of TB cases. In 2023, it is estimated that there were 3,000 TB cases in Jayapura, with treatment success rate of 67%. [8] With such high internet penetration, cellular phone network coverage and the TB status in Jayapura, integrating digital adherence technology into a healthcare delivery system in this region of Papua holds promise to improve TB outcomes.

In 2021, Indonesia's Ministry of Health introduced the Blueprint Digital Health Transformation Strategy 2024, offering stakeholders and players in the health industry a comprehensive overview of the country's trajectory and roadmap for digital health transformation in the coming years. This initiative was further reinforced by health ministerial decrees in 2022, emphasizing the implementation of electronic-based government systems in healthcare and digital transformation strategies. The third priority activity agenda outlined in this blueprint, aims at fostering the development of a health technology ecosystem where it expanding the telemedicine technology and integrate or creating an innovative health technology product by collaboration with government, industry, research institution and public. [32,33] The integration of digital adherence technology to enhance TB outcomes in Indonesia aligns with this priority.

In response to the identified need for tailored DATs in Papua, we adapted and refined the TB Treatment Support Tools (TB-TST) intervention for a Papuan population and context and rebranded it as the Samocare app which translates from Papuan Malay to “I will care”. The TB-TST intervention, combines a mobile app with a direct drug metabolite test for remote adherence confirmation and connects patients with treatment supporters, has undergone iterative development in Spanish and was demonstrated to be feasible and acceptable in a pilot randomized

control trial.[34] The Samocare app was adapted and refined to Papua's community needs and preferences using a three-phase discover, design and build, and test (DDBT) framework[35] (Figure 1) a multiphase process that aligns with established Human Centered Design HCD principles. Chapter 3 outlines the details of the design and build phase. The purpose of this chapter/paper is to present the third test phase (Figure 4.1) to evaluate the usability, feasibility, acceptability, and early impact of the Samocare intervention on TB care in Papua and to identify areas for improvement.

Figure 4-1: Process of adaptation and refinement of TB-TSTs using DDBT framework



4.3 METHODS

This single-arm prospective pilot study was approved by the University of Washington Institutional Review Board (STUDY0015296 MOD00013871), the Provincial Unity of Nations and Politics Department of Papua Province (No.070/108/2022) and received a permit from Rumah Sakit Umum Daerah Jayapura (RSUD Jayapura) (No.06/070/SDM-LITBANG/III/2022).

We enrolled 20 participants newly diagnosed with TB from July to October 2022 to assess the usability, feasibility, acceptability, and initial impact of the Samocare intervention.

4.3.1 Setting

This study took place at the Voluntary Counseling and Testing TB (VCT-TB) clinic of RSUD Jayapura (Jayapura Hospital) in Jayapura, Papua-Indonesia. Jayapura is the capital of Papua with a population of 400,000 and TB incidence rate of around more 3,000 yearly.[36] the VCT-TB clinic is one of the outpatient clinics of Rumah Sakit Umum Jayapura (Jayapura Hospital) that provides care to HIV/AIDs, TB, and DR-TB patients. This is the only outpatient clinic in Papua that offers integrated TB and HIV services. In 2021, the clinic treated 275 susceptible TB patients.[37] As the referral and largest hospital on the island, the clinic serves a diverse population in terms of race and ethnicity, including both Papuan and non-Papuan individuals. Patients come not only from the surrounding areas but also from across Jayapura city.

4.3.2 Samocare App Intervention

The samocare intervention, adapted to Papua's community through three refinement phases (detailed in Chapter 3), has two interfaces: one for individuals with TB and a dashboard for healthcare providers. Similar to TB-TST, the individuals with TB app allows self-reporting of TB medication intake, potential side effects, and weekly urine test photos. It provides TB information, alarms, appointment reminders, a treatment progress calendar, and messaging for communication with treatment supporters or discussion forum with other patients. The treatment supporter interface, accessible on desktop or smartphone, includes a cohort summary task list, patient profiles, progress tracking, appointment links, urine test photo history, and messaging for

direct communication and forum discussion monitoring. Based on end users request, daily motivational messages are featured on the patient's home page. (detailed app presented in Multimedia Appendix 1)

The app is a progressive web app that operates similarly to a native app. It is compatible with both Android and iOS operating systems, although it offers limited push notification functionality on iOS. The use of this app requires a smartphone with access to Wi-Fi or cellular data.

4.3.3 Recruitment

Research nurses introduced the study to individuals newly diagnosed with TB during their first clinic appointment to describe the study, establish eligibility, and enroll participants. To be eligible for the study, patients must be 18 years or older, diagnosed with susceptible TB/first-line TB. All individuals who are suspected to have TB need to take Rapid molecular essay test for diagnosing TB. Those with results indicated the presence of Mycobacterium TB considered as positive for TB and will encourage to start the treatment immediately. Those with result indicated Mycobacterium TB not detected will need to take more examination and will be determine if they need to start the treatment based on the clinical diagnosis. Additional criteria were: possess a smartphone, and have no plans to relocate during treatment. Initially, we excluded individuals with TB-HIV and extrapulmonary TB. However, during recruitment, the treatment supporters recommended including all diagnosed TB participants aged 18 and older who owned smartphones to enhance the clinic workflow. If participants were interested and met eligibility criteria, they were enrolled after the consent process.

All five TB nurses at the clinic who focused on treating adult TB patients participated in the study as treatment supporters.

4.3.4 Study Procedures

After enrollment and completing a baseline questionnaire, participants received about 30 minutes of training from a nurse and research assistant on using the app. They were assisted in downloading and pinning the app to their phone's home screen. Participants were instructed to explore all the app features and given verbal operating instructions. To ensure functionality, participants were asked to complete a test report by reporting medication intake, sending a picture, and messaging the treatment supporter.

Participants were instructed to report their daily medication intake activities each morning and were encouraged to contact the treatment supporter if they encountered any problems (i.e., forgot login password, changed phone number). Once a week, on a random day, participants receive a notification to submit a picture of a completed test. Usual care included clinic visits to be evaluated and pick up drug refills every two weeks for six months, and sputum testing at the end of the second month, the last week of the fifth month, and the last week of the sixth month. For this study, based on the agreement of the treatment supporters during the refinement phase 3/field testing, participants were asked to return to the clinic after one week to monitor their response to the TB drugs and assess their ability to use the app and resolve app related issues.

Participants were asked to complete a usability questionnaires and followed by a 30 minutes interviewed during their drug refill visit of week 8 and week 24. Participants were additionally asked to fill in the exit survey in the week 24.

If patients were unable to be interviewed at that time due to time constraints, another time was arranged to return to the clinic or to conduct the interview over a phone call. Participants

received compensation for their time of US $5 equivalent to complete the baseline survey and for each interview completed.

Treatment supporters: The TB nurses underwent comprehensive training facilitated by the principal investigator and research assistant that included a full day training followed by a week of field testing (described in Chapter 3). The training session included procedures to recruit participants and an in-depth exploration of the features of the treatment supporter interface, including adding a new patient and how to monitor participants. They also received training on the patient-facing app, to learn the download procedures (i.e., pinning the app to the home screen), and how to teach patients about the app's features. Field testing week allowed nurses to understand the app workflow and identify potential issues before piloting. Including response protocol for handling patient issues, such as missed reports and setting text reminder limits before calls or home visits.

During pilot testing, nurses rotated as treatment supporters every two weeks, sending messages to patients who had not reported by 11 a.m. and scheduling home visits if no report was received for two weeks and a drug refill was missed. Nurses and the research team met biweekly to discuss issues and at the end of the study, nurses were interviewed for 30-60 minutes to gather their perceptions and experiences.

4.4 DATA MEASUREMENT AND ANALYSIS

4.4.1 Variable Measurement

The baseline survey collected participant age, sex, diagnosis, rapid molecular test results, race, education, occupation, history of BCG vaccine, history of past TB treatments, type of transportation to the clinic, and smoking status. We also collected technology-related experience,

including years of smartphone use, smartphone ownership, type of phone plan, familiarity with using the apps on the phone, and particularly WhatsApp.

Feasibility was assessed for recruitment by the percentage of eligible participants who agreed and declined participation, app log data for self-report adherence, and adherence test submission rates. The percentage of self-reported adherence was calculated by dividing the number of days reported by 180 (days of standard treatment). For patients who underwent longer courses of treatment (e.g., extrapulmonary TB), we assessed the first 180 days of treatment. Self-reporting engagement was categorized as low (less than 60% reports submitted), medium (60-90%), and high (more than 90%). The test submission rate was determined by comparing the number of submitted photos to the number requested.

Usability was assessed using the mHealth App Usability Questionnaire (MAUQ), a 21-item tool with 7-point Likert (strongly disagree to strongly agree) questions with the highest possible score of 147. The overall Cronbach alpha was 0.931. Three factors correspond to three constructs, or subscales, on the MAUQ: ease of use and satisfaction (8 items, MAUQ_E), system information arrangement (6 items, MAUQ_S), and usefulness (7 items, MAUQ_U). Their Cronbach alpha values were 0.895, 0.829, and 0.900, respectively, which indicated strong internal consistency.[38]

Acceptability was assessed in the exit survey by asking patients to rate the app and test ease of use on a scale of 1-5 (1= very difficult, 5=very easy) and if they would recommend the app to others starting treatment (1=would not recommend, 5=highly recommend). Surveys were stored in RedCap. Interviews were conducted to understand acceptability and the experiences of patients and treatment supporters using the app. Interviews were conducted by the principal investigator (AS), were audio recorded and transcribed using Whisper by OpenAl[39], and checked for accuracy by the research assistant (AR).

Treatment outcomes were defined using the WHO TB treatment outcome definitions updated in 2021: treatment failed, cured, treatment completed, died, lost to follow-up, not evaluated, and treatment success.[40] Treatment success is the sum of cured and treatment completed.

4.4.2 Analysis

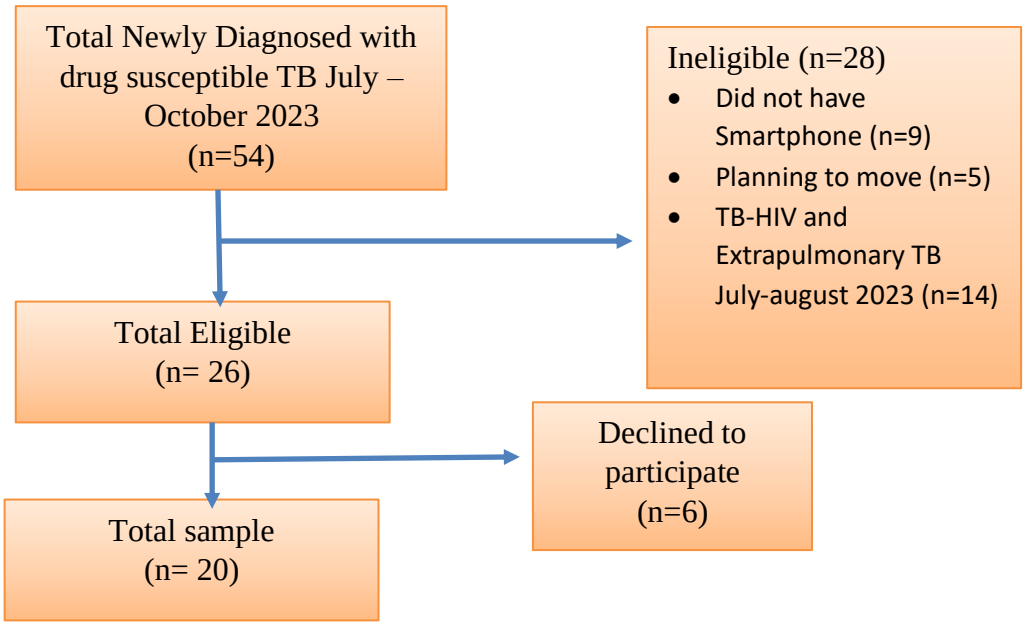
The quantitative data were analyzed using SPSS version 29. We calculated descriptive statistics of participant baseline characteristics and technology-use. To determine the usability of the app, The total and average usability scores and standard deviation were calculated for each subscale of MAUQ and compared across the time points (Week 8 and Week 24). The higher the overall average score, the higher the usability of the app. Feasibility was reported with the average percentage of daily self-reported, test strip photo submission, and level of engagement. Treatment outcomes were reported using percentages. Acceptability was analyzed by averaging rating scores from the exit survey and thematic analysis of the interviews. Qualitative data were analyzed using Braun and Clarke's six steps of thematic analysis.[41] Coding team members (AS, AR) first read all the transcripts to get familiar with the data and developed initial codes separately. Transcripts were coded in their original language, Bahasa by research team members bilingual in English and Bahasa (AS and AR). Coders meet weekly to compare the codes and iteratively develop a codebook, reviewing the meaning and example of each code. The codes were then categorized, and main themes identified. The researcher then met several times to refine the themes when a new theme emerged. Exemplar quotes to be used in the article were translated to English. We used Atlas.ti software 23 to assist in the qualitative data analysis process.

4.5 RESULT

4.5.1 Participant Characteristics: Recruitment (Feasibility)

During the recruitment period 54 individuals received a diagnosis of drug-susceptible TB, 26 met eligibility criteria, six declined to participate in the study, and 20 were enrolled and completed the baseline survey (Figure 4.2). At the second month follow-up visit, 15 completed the MAUQ questionnaire and 8 were interviewed. At the six-month follow-up, 16 participants completed both the exit survey and interview, and 15 completed MAUQ questionnaires.

Figure 4-2 Diagram with enrollment



The average age of the participants was 32.4, range 18-72 years (SD = 14.0) and 55% were female. A majority 60% (12/20) identified as Papuan and 40% non-Papuan, and 65% completed a high school education. Their primary occupations varied, with many working as laborers, housewives, or unemployed. Among the 20 patients, two did not undergo the rapid molecular test, and out of those who took the test, two received a "not detected" result. Regarding vaccination and previous TB treatment, 80% of patients reported receiving the BCG

vaccine, while 25% had previously undergone TB treatment. Regarding transportation to the clinic, the majority, 60%, used motorcycles as their primary mode of access. Additionally, 75% reported never smoking, and 80% indicated they never consumed alcohol. Table 4 shows the baseline characteristics.

Table 4-1. Baseline characteristics of patients (n=20)

Demographics	**Value**
Age (years), Mean (SD)	32.4 (14.2)
Diagnose, n (%)	
Pulmonary TB	11 (55)
Pulmonary TB+HIV	3 (15)
Extrapulmonary TB	3 (15)
Extrapulmonary TB+HIV	3 (15)
Rapid Molecular Test result, n (%)	
MTB detected high	3 (15)
MTB detected medium	5 (25)
MTB detected low	2 (10)
MTB detected very low	4 (20)
MTB not detected	2 (10)
Not Tested	2 (10)
Type of drug, n (%)	
fixed dose	18 (90)
Loose Dose	1 (10)
Sex, n (%)	
Male	9 (45)
Female	11 (55)
Race, n (%)	
Papua	12 (60)
Non-Papua	8 (40)
Marital Status, n (%)	
Married	8 (40)
Single	12 (60)
Education, n (%)	
Primary school	3 (15)
Middle school	1 (5)
High school	13 (65)
Diploma	1 (5)
Bachelor’s degree	2 (10)
Occupation, n (%)	
Government employee	3 (15)
Private sector	6 (30)

Housewife	5 (25)
Student	1 (5)
None	5 (25)
Insurance type, n (%)	
National insurance	10 (50)
Papua's insurance	9 (45)
None	1 (5)
History of BCG vaccine, n (%)	
Yes	16 (80)
No	4 (20)
Taken TB treatment previously, n (%)	
Yes	5 (25)
No	15 (75)
Transportation to clinic type, n (%)	
Public transportation	6 (30)
Motorcycle	12 (60)
Car	2 (10)
Smoking Status, n (%)	
Never	15 (75)
Sometimes	1 (5)
2-3 times a week	1 (5)
Everyday	3 (15)
Alcohol consumption, n (%)	
Never	16 (80)
Sometimes	2 (10)
2-3 times a week	1 (5)
2-3 times a month	1 (5)
Everyday	0 (0)

In terms of technology use (Table 4.2), the median duration of smartphone usage among participants was seven years, three reported sharing smartphone ownership with their families, and all used prepaid smartphone plans. Eleven (55%) reported that they were familiar with using various apps on their smartphones, but all had exposure to the WhatsApp messaging system (50% very familiar, and eight expressed a general familiarity).

Table 4-2. Patient's technology related characteristics (n=20)

Demographics	**Value**
Years using Smartphone	7 (3.34)
Smartphone ownership status, n (%)	

Personal phone	17 (85)
share with family	3 (15)
Type of Phone Plane, n (%)	
Prepaid	20 (100)
monthly billing	0 (0)
Familiarity with using apps, n (%)	
Very Familiar	4 (20)
Familiar	11 (55)
A little Familiar	3 (15)
Not Familiar	2 (10)
Familiarity Using WhatsApp, n (%)	
Very Familiar	10 (50)
Familiar	8 (40)
A little Familiar	10 (2)
Not Familiar	0 (0)

The treatment supporters ages ranged from 30-45 years old, four were male, and employment duration at the clinic ranged from 1 year to more than 20 years (Table 4.3). Two held master's degrees, while the other two had bachelor's degrees. Three of the treatment supporters were non-Papuan, and three had permanent positions in the hospital, while the remaining two were on long-term contracts. Four out of five treatment supporters preferred using their own smartphones to the computer desktop interface to monitor the participants.

Table 4-3. Demographics characteristics of treatment supporters (n=5)

Demographics	**Value**
Age (years), Mean (SD)	41.80 (7.25)
Sex, n (%)	
Male	4 (80)
Female	1 (20)
Education, n (%)	
Master degree	2 (40)
Bachelor degree	2 (40)
Associate's degree	1 (20)
Race, n (%)	
Non-Papua	3 (60)
Papua	2 (40)

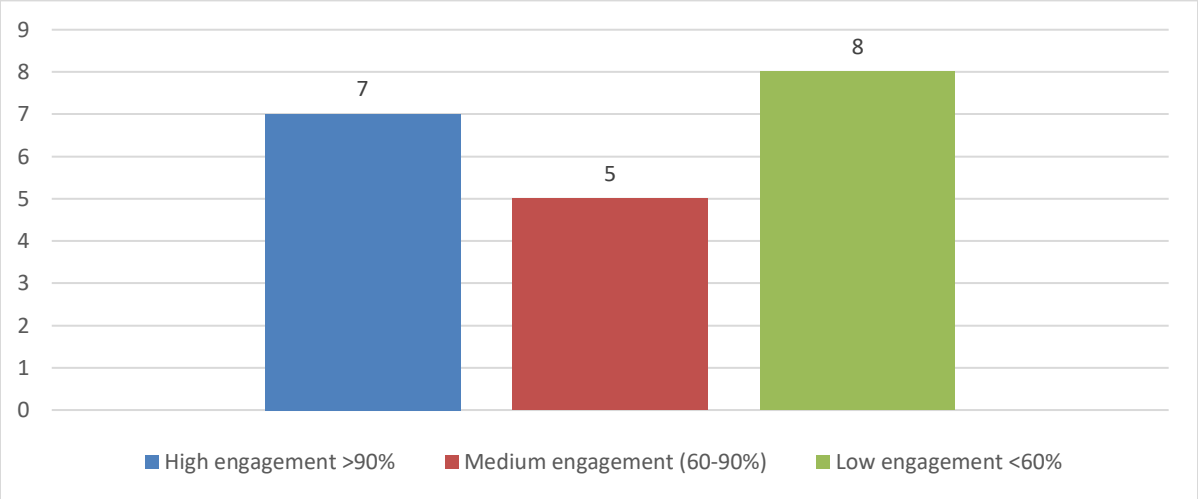
Working status n (%)	
Permanent staff	3 (60)
Contract	2 (40)
# years working in the clinic, Median, SD (range)	3, 8.9 (1-22)
Preference device to access the App	
Smartphone	4 (80)
Computer Desktop	1 (20)

4.5.2 Feasibility: User Activity

Daily self-report of medication adherence: The average daily self-reported adherence through the app was 68% (mean 68.65, SD 27.97; range 24-100). Figure 4.3 shows a 'heatmap' of reporting for each participant. All participants were actively sending daily reports in the first two weeks and some decreased or stopped reporting overtime and three died during treatment. When assessing daily self-reports by engagement level of the 17 participants (Figure 4.4), seven (35%) had high engagement (>90% self-reporting adherence; three reported 100%), five (25%) had medium engagement (60-90% reports), and 8 (40%) had a low engagement (reporting less than 60%). Of those with a low engagement level, two reported having lost their phone during the intensive phase of the treatment and one was lost to follow-up. Of the participant who died, they had low reporting rates despites of several home visits and calls made by treatment supporters.

Figure 4-3: Heatmap of daily self-report medication intake.

Figure 4-4: Level of engagement based on self-reported adherence.



Test strip report: The average percentage of urine metabolite test photo submissions was 30%, (mean 30, SD 30, range 0-83%).

4.5.3 Usability

The MAUQ scores were high across both timepoints signifying overall high usability (Table 4.4). The scores across all three MAUQ subscales increased from 8 weeks to 24 weeks with a total mean score of 125.53 (SD 27.66) and 132.33 (SD 10.41), respectively. One item, assessing whether the app met users' expectations in terms of functionality and capabilities, did not change.

Table 4-4. Usability Scores at 8 Weeks and 24 Weeks

	intensive phase (week 8th)				Follow-up phase (week 24th)			
MAUQ Questionnaire	**n**	**Min**	**Max**	**mean (SD)**	**n**	**Min**	**Max**	**mean (SD)**
Ease of use and satisfaction	15	10	56	48.07 (10.98)	15	45	56	50.6 (12.8)
system information arrangement	15	8	42	35.33 (8.16)	15	32	42	37.26 (3.5)
usefulness	15	12	49	42.133 (9.18)	15	36	49	44.46 (4.1)
All combined	15	30	147	125.53 (27.66)	15	113	147	132.33 (10.41)

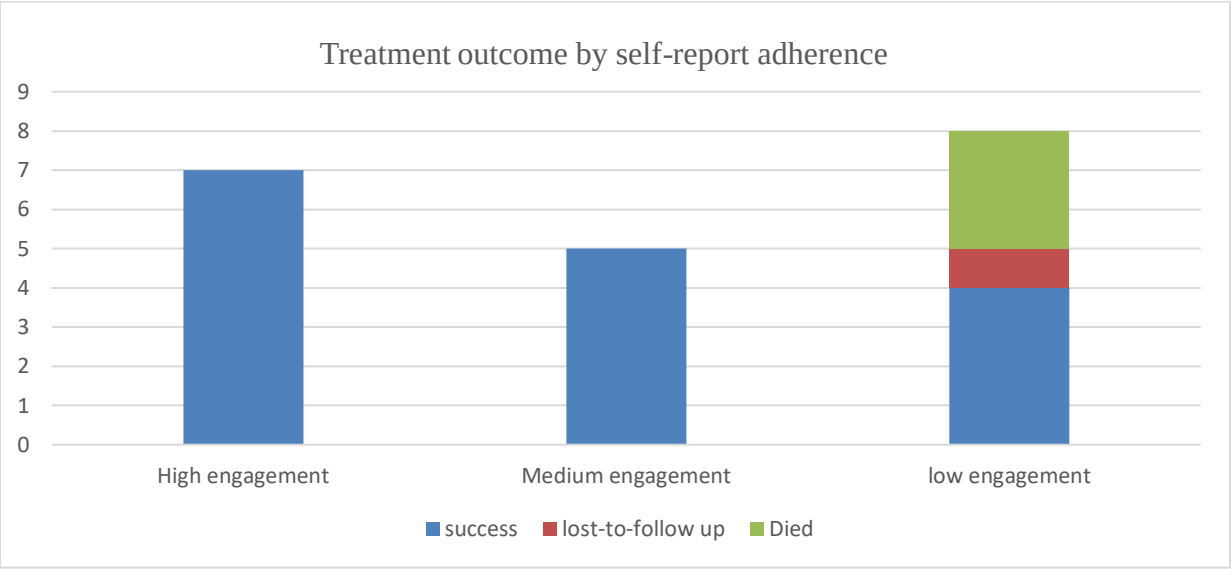
4.5.4 Treatment outcome:

Table 4.5 presents the final treatment outcomes. Sixteen participants successfully completed treatment; however, one had 2 BTA+ (Indicated there is still moderate bacterial load) in the last sputum smear test. Among the 11 diagnosed with pulmonary TB, eight achieved treatment success, while two died during the second and third months of treatment, and one was lost to follow-up, having abandoned treatment for over two months. Among the three participants diagnosed with pulmonary TB+HIV, two successfully completed their treatment, and one died during the fourth month of treatment. All participants with extrapulmonary TB and extrapulmonary TB+HIV successfully completed their treatment. When categorizing the patients based on their activity in reporting through the app (Figure 4.5), those reporting more than 60% successfully completed treatment. In comparison, all the participants that had poor treatment outcome were in the low engagement category.

Table 4-5. Patients Treatment Outcomes

	Number of patients	**Treatment outcome**		
		Treatment success	**Died**	**Lost to follow-up**
Pulmonary TB	11	8	2	1
Pulmonary TB+HIV	3	2	1	0
Extrapulmonary TB	3	3	0	0
extrapulmonary TB+HIV	3	3	0	0
Total	**20**	**16**	**3**	**1**

Figure 4-5: Treatment outcome by self-reported adherence



4.5.5 Acceptability

In exit surveys, participants reported the app easy to use (average rating 3.9), the test strips as easy to use 4, and that they would recommend to others starting treatment 3.9. Three participants who were hesitant to recommend the app acknowledged its significant benefits during their treatment but expressed a hope that others would not need to use it, implying they wish no one else would get TB.

Interviews with patients and treatment supporters assessing their perceptions and experiences with the app and identified three main themes: perceived benefits, perceived challenges, and recommendations for improvement.

4.5.5.1 Perceived Benefits

Promoting routine and supportive treatment experience:

Patients stated that the app's requirement for regular reporting and subsequent monitoring by treatment supporters played a crucial role in helping patients develop a disciplined routine for

medication adherence and push forward to finish the treatment. This routine was further reinforced by the app's features, such as a color-coded calendar and progress timeline for appointments, which kept patients informed about the duration of their treatment and what to expect in the coming months. Overall, the app fostered structure and improved their treatment experience.

> *"The first experience, I was reminded more about the time to take medicine, to get the medicine refill, and like there's some important information like that, that's it.. It's more like feeling that someone is paying attention to me. At least there's a little task for this, right, because usually if there's no task like that.. Oh, it's because of this application, so we are given a task to report here if we have any complaints or something." Female, 26 Years*

Patients expressed the app facilitated better medication adherence and increased their optimism to finish the treatment. The daily motivational behavior-change messages, direct messages from treatment supporters, and push notification brought sense of being valued and cared for.

> *"On the phone screen [push notification] "Hi [participant name],how are you today? Have you taken your medication yet?" It's like someone cares about me, LOL." Male, 25 years*

For the treatment supporters, they reported that the real-time patient updates and status was what they need to treat their patients compared to the current paper-based system. Through this system, they were able to receive early notification about issues their patients were experiencing, and early warning for potential non-adherence. The cohort review feature allowed them to prepare the planning for each patient in advance. The platform features made them feel more

aware of their patients, and that they could be more helpful and involved in improving their care delivery.

> *"When they don't take their medication, we initiate communication, and we explore, and from there we can understand...What actually becomes the obstacle that prevents them from taking their medication. What are the challenges until they don't check off."*
>
> *Treatment supporter, Male 32 years*

Flexible access to care and information – reducing time (efficiency) and costs associated with travel.

Patients reported that the app allowed flexibility, allowing them to access educational information anywhere and anytime and message treatment assistants to report issues or request additional information. They noted that this flexibility was not possible from in-person visits due to the limited time healthcare providers can spend with each patient. The app served as an educational tool, enhancing patients' understanding of their disease, the correct way to take their medication, and the consequences of discontinuing treatment, empowering them to take a more active role in managing their health. Additionally, patients appreciated that the app reduced the time and cost associated with unnecessary clinic visits. They could use the app to quickly address minor issues and get guidance, thereby saving time and avoiding travel expenses.

> *"It [app]is helpful because we don't have to come here (the clinic) go through the hassle of contacting the healthcare workers when we need something. It's really helpful. If there's something we need to ask, we can just chat and wait for their response on our phones." Female, 25 Years.*

For treatment supporters, the app reduced their workload by improving time efficiency and reducing the need for extra home visits, as patients could be monitored using the app. In addition, the education feature helped deliver education to patients that they could not deliver due to limited time during clinic visits.

> *"….it saves me time from having to go down to their house, but through this app, I can make contacts and all sorts of things,… helps me so my time is not wasted much.. and to make it easier for me to monitor TB patients. Treatment supporter, Male, 43 years.*
>
> *"Sometimes…there are patients who ask questions. Well…. we just find a link that has a video for education… read it here (refer to app education feature) it's clear…" Treatment supporter, Male, 43 years*

Enhanced patient-treatment supporter communication

Most participants reported that they used the message feature for direct communication with their treatment supporters when needed. They emphasized that this component was essential for improving communication between patients and healthcare providers.

> *"Because the most important thing that we need is to communicate with the nurses. With this app, it is much easier to communicate." Male, 33 Years.*

Similarly, the treatment supporters felt the app allowed them to meet their goal to provide patient-centered care by improving communication.

> *"Oh, as for me, ma'am, the role of a nurse, yes, is very helpful because if we use this application to its fullest, I believe our role as nurses is very supportive in ensuring the patients continue to take their medication. So, by us communicating... Educating... And motivating... Certainly, the role of the nurse is very helpful, because as you, ma'am, have*

taught us, we must engage in therapeutic communication, right? Treatment supporter, Male, 32 years

Test strips supported adherence habits and honest reporting

Patients stated that the test strip allowed them to have a regular habit of anticipating and feeling obligated to take the medication since they felt being observed and evaluated using the test. Other patients mentioned that the test helped control their adherence and honesty.

"For me, it's [adherence test] good because it helps control us as patients, right? Like, say, we take the medication but sometimes we skip it. But it can be detected from the test strip. If we use the test strip, it can show whether we've taken the medication or not. So, for me, it's better; it puts pressure on us as patients. It's good in my opinion." Female, 28 Years

Treatment supporters appreciated being able to confirm patient adherence remotely, tackling their challenges in monitoring due to time constraints and a shortage of healthcare providers. They felt that it could provide an effective solution for decreasing MDR-TB cases, particularly where drug resistant cases are on the rise.

"We can't monitor our patients at home right? We only know they come to the clinic every 2 weeks, that's how we mark it… Through this app, we can understand, later it can be known through their INH assistance (refer to test strip), right? The one with the INH… the test strip….Yes, detection of INH. So it's really helpful…. So, it can decrease the number of our drug resistance patients. Treatment supporter, Male, 32 years.

4.5.5.2 Perceived barriers

Technical barriers – app technical issues and internet connection

Patients reported several technical issues with the app, including problems with push notifications, alarms that triggered without sound or sometimes did not appear on the screen, and difficulty accessing the app directly, sometimes having to access the app through the internet browser instead. The most common issue was internet access; patients frequently experienced poor connectivity or ran out of internet data, hindering their ability to submit reports. Although the tool only uses very little data, Most participants had pre-paid data phone plans and paying for internet data is challenging for those from middle to low socioeconomic backgrounds. Several patients stopped reporting temporarily due to changing to a new phone and two patients could not afford a replacement phone when theirs broke during the second month of the treatment.

> *"The only constraint is that sometimes I can't access it directly on my phone." Male, 43 Years*
>
> *"But this phone of mine doesn't have a SIM card, so when I want to report something at home using Wi-Fi, then Wi-Fi is down." Female, 22 Years*

Patients encountered several issues with the test strips, such as difficulties uploading the test result photos due to blurred image and request to re-upload the photo after the test had been discarded. One patient mentioned a leaking problem with the test strip. Additional challenges included losing the tests while using public transportation, taking medication before receiving the notification to perform the test, forgetting to take the test due to busy schedules, and technical issues such as difficulty uploading pictures or having a phone with poor camera resolution.

"Maybe for me, what frequently happens is that it [the app] asks for a re-upload of the strip. It's easy actually, but I throw away the test strip after i uploaded the picture. Then when I open the app again, it [the app] asked to re-upload the picture" Male, 27 Years

For the treatment supporter interface, the team encountered some issues during monitoring. Treatment supporters reported errors when attempting to open the app or sign into the app. Additionally, the push notification was unreliable, as supporters did not receive alerts when patients requested support. This led to delayed responses or lack of awareness of support requests until the app was manually checked.

"For this app, for me…. The warning… yes the warning (refer to push notification). Like WhatsApp when I see there is 350 messages that I need to open.. this app did not give notification on my phone" Treatment supporter, male, 32 Years

In addition, treatment supporters reported inconsistent access to clinic Wi-Fi, often requiring them to use their personal internet data. At times, they had to search for a better internet connection outside the clinic or in other locations with more reliable internet access.

"For me, it's about the main point, ma'am, to the data [internet data] That's it. I have to talk about that because it relates to our current condition and everything, that's one of the reasons. I have issues with the data.." Treatment supporter, Male, 39 Years.

Other barriers:

Participants reported various ways they used the app. The majority stated they used it daily to self-report their medication intake, typically doing so in the morning immediately after waking up. However, this routine led to a common issue: they often forgot to submit their test strip because they had already taken their medication, mistakenly thinking they had to conduct the test

prior to taking their medication. There was also a group of patients who engaged with the app less frequently, opening it only about once a week or whenever they remembered. Despite this sporadic use, these individuals stated that they maintained regular medication schedules. Another common reason for not reporting was that participants were too busy and forgot to report. Patients mentioned that messages from treatment supporters and reminders from the app helped them stay on track with their treatment.

> *"No… yes, I forget about taking picture (refer to test strip result), also reporting. Maybe every five days… not really everyday" Male, 25 Years*

Three patients experienced severe side effects due to other complicated diseases (HIV) and conditions such as early term pregnancy or sensitivity to drugs, making them weak and limited their activities.

> *"It's just normal, although sometimes I also forget. Forget to report. It just because after taking medicine, I still feel effects, especially since I take Lepo, and I think Lepo is strong, it sometimes makes me nauseous even though I don't vomit. My stomach feels all churned up.. So, sometimes the point is I have taken the medicine, but the next day I forget how many pills there were, so sometimes someone from here [referring to the app] also says, don't forget to take your medicine, come on, report something." Female, 26 Years*

An unexpected barrier arose from the treatment supporter's slow response times. Several participants expressed frustration with delayed responses to their support requests, often leading them to solve the problem themselves. One participant specifically mentioned that her

enthusiasm for reporting through the app decreased because she did not receive feedback immediately when she reported side effects.

> *"Well, I do reporting, but, well this is one of the weaknesses, not a deficiency but the staff are slow to respond, huh…..Sometimes it takes one or two days to get a reply, that's how it is. Because sometimes when we need something or have something to ask, and the staff are slow to respond, we also get confused." Male, 25 Years*

Initially, treatment supporters used the app daily. However, as their workload increased due to caring for TB, drug-resistant TB, and patients with HIV, their frequency of app usage decreased, sometimes to as little as once a week. Managing a diverse patient population, including those with HIV/AIDS, alongside their regular duties, made it challenging to maintain consistent engagement with the app. This situation underscores the struggle of balancing direct patient care with technological monitoring. Additionally, the diverse needs of patients and rotating schedules among providers complicated communication and consistent patient monitoring through the app.

> *"Perhaps because each of us has a very high workload, so each of us is focused, and secondly, our lacking are communication….. and coordination" Treatment supporter, Male, 43 Years.*
>
> *"As for me, I'm really constrained by this. We're working quite intensely, with a lot to do, especially with the reports [refer to national TB report]. So, in order to be able to work on this, I only look at it once a week. I monitor it. I keep an eye on it, so it's not very intensive, ma'am. It's less intensive because there are reports related to Information system of TB in community (SITK) and Information system of TB (SITB) that I have to*

work on. And there are also many patients in our care that need attention, including those who come for services every day." Treatment supporter, Male, 32 Years

4.5.5.3 Recommendation to Improve Samocare Intervention

Recommendation for the Patient interface

Patients' recommendations primarily focused on enhancing user engagement and app functionality. Key suggestions include improving the push notification system for more effective alerts and reminders. Introducing a "last seen" status for the treatment supporter messages to minimize delayed responses from treatment supporters to promote prompt communication. Additionally, displaying the count of participants in group discussions could encourage more active involvement by demonstrating to users that they are part of a larger community. Integrating dynamic animations into the education feature and giving it prominence on the front page would also enhance the appeal and accessibility of educational content. For the test strip component, patients suggested improving the photo submission feature to eliminate the necessity for multiple uploads and shortening the waiting period for test strip results, addressing practical challenges faced by patients.

"Yes. Or features like 'last seen' so we know, oh, this treatment supporter is active in the application or not, something like that. If it's like this, it's like it's purely empty, just like that." Male, 25 Years

Recommendation for the Treatment Supporter Interface

Recommendations from the treatment supporters included optimizing and integrating into the national TB data program. To tackle the issue of delayed responses, a push notification should be added to notify the treatment supporter when a request for help is submitted. Other alerts should

be added to notify treatment supporters about patient treatment milestones such as times for lab tests, missed appointments, and reports not submitted by 11 am. Implementing an auto-reply feature for patient messages could enhance response times from treatment supporters. Other enhancements to streamline the monitoring process included appointing a central individual responsible for overseeing patient monitoring who could update treatment supporters on essential matters, specifically those requiring medical advice. Integrating the app with hospital systems could improve its success by securing commitment from both leadership and treatment supporters prior to implementing it on a larger scale.

> *For me personally…, because indeed here we are, not just me, yes... Everyone, almost everyone works on all patients' cases, whether DR-TB, active TB, or HIV, not to mention if the patient is a child, we have to do contact investigation and so forth. So, there's quite a lot of responsibility. Well... If we implement this application, it's better if only one person holds it and he can monitor it and even if there are problems (request medical decision).. Then he can inform us so we can follow up together. But if it's about holding this application, my personal suggestion is it's better if it's just one person, because, that way, if this works. He can go to Information system of TB (SITB) too, synchronize it" Treatment supporter, Male, 32 years.*

4.6 DISCUSSION

To our knowledge, this study represents the first evaluation of a digital adherence technology tailored to individuals in Papua, utilizing a human-centered design approach and integrating the app into healthcare services. This study serves as the pioneer of mHealth in the region, co-designed and tested with end users. Despite the resources constraints in Papua, the Samocare app demonstrated feasibility and acceptability among both individuals with TB and

healthcare providers. Additionally, this study contributes to the limited body of research in Indonesia to assessing the feasibility and acceptability of mHealth interventions, particularly for infectious diseases.

The Samocare intervention aimed to enhance TB prevention and care in Papua by supporting treatment adherence. Ensuring adherence to treatment poses a significant challenge, as it necessitates daily commitment that can be difficult to verify.[42] In Indonesia, adherence measurement still heavily relies on paper-based self-reported instruments, often corroborated by the number of pills remaining when patients come for drug refills. While self-reported instruments offer advantages such as being low-cost, noninvasive, and feasible, particularly in countries with high disease burdens, they have been found to overestimate adherence compared to alternative methods.[42-45] In our study, while self-reported adherence via the app averaged 68%, possibly due to technological constraints or habit formation challenges, 80% completed treatment compared to 71% in 2021 at the same facilty.[37] Reporting through a mobile app requires patients to develop new habits, which can be challenging, especially for those with lower technology literacy which can contribute to lower self-reporting than actual adherence. A metanalysis study of implementation feedback of six DATs reported the same barrier such as network coverage and lost phone impact the report although the patients still taking the medicine.[46] Two lost their phone in the early stages, impacting the overall adherence rate. Recognizing the limitations of self-report adherence methods, there is a critical need for more accurate and objective measures, such as drug metabolite tests.[47] This study represents the first in Indonesia where the drug metabolite test method was used to remotely verify adherence. Although challenges like technical errors, forgetfulness, and lost test strips hindered test submissions, the method shows promise in improving adherence accuracy.

Since 2018, the patient-centered approach has been the cornerstone of the end TB strategy, prioritizing patient needs in care provision.[48] Aligning with this approach, mHealth aims to improve accessibility and promote patient-centered care.[49,50] Our interviews with participants revealed several benefits of the app, including reduced time and travel to clinics, increased knowledge through the education feature, feeling supported, and improved communication with healthcare providers. These benefits directly address non-adherence challenges reported in Jayapura, Papua, as documented by Ruru et al.[19] Similar to previous studies investigating the benefits of mHealth tools for real-time reporting to healthcare providers,[49-51] the treatment supporters, found significant value in real-time reporting feature through the app. This feature, which presented summarized lists of patient issues, allowed for a proactive approach, facilitating early intervention for high-risk patients and reducing the risk of loss to follow-up. The app enabled the nurses to effectively track their patients, even successfully reengaging a participant who had initially been lost to follow-up and restart their treatment. Additionally, the app served as a tool to receive updates on patients who unfortunately passed away during treatment, aiding in TB tracing efforts within patient's families and communities. Moreover, the app provided nurses with comprehensive data for enhanced treatment care and served as an effective communication tool for collaborating on care planning. Notably, the app played a pivotal role in improving communication between healthcare providers and patients, with participants expressing increased comfort in communicating through this digital platform.

While real-time reporting provides valuable insights as an early warning system for high-risk populations, three of our participants died. Through the app logs, treatment supporters were able to bring them back to the treatment after several times abandoning the treatment by numerous calls and home visits following the protocol that has been established during field

testing. Despite efforts by treatment supporters to encourage adherence, these participants unfortunately died in the same hospital. However, due to the non-integrated medical records, treatment supporter was only notified after reaching out to the patients' families upon noticing a lack of reporting and being unable to contact the patients through the app. Learning from our participants cases, the mortality rate among participants in the clinic is concerning, notably higher than the 2021 data, where six out of 281 patients died.[37] This finding may signify an underreporting of TB deaths in prior years due to limited notification mechanisms regarding patient status during treatment through paper-based and unintegrated medical records. Especially during the COVID-19 pandemic, the TB service disruption likely contributed to diagnostic and treatment delays that particularly affected individuals with TB, leading to a surge in the number of deaths and underreporting of TB-related deaths.[52] The number of TB mortality in the clinic might be higher than actual data. Accurate treatment outcome data is critical for effective program monitoring, evaluation, and resource allocation in TB prevention and care.[40] Through the Samocare app there may have been an increase in data accuracy with TB related deaths being detected sooner.

The decline in participant utilization of the app over time aligns with trends seen in other mHealth trials.[51] Despite challenges like participants losing their phones, our finding showed a similar pattern. The heatmap illustrates consistent reporting in the first two weeks, followed by a gradual decrease. Interviews with participants shed light on various factors contributing to this decline, including forgetfulness amid busy schedules, complications from concurrent health issues like drug side effects HIV, or pregnancy hindering app use, and dissatisfaction from delayed responses from treatment supporters. While mHealth apps offer potential benefits, research indicates moderate to low acceptance among healthcare providers.[54,56] Additionally,

differences in skills and acceptance levels among healthcare workers may explain participant disappointment, especially since nurses agreed to rotate monitoring every two weeks.[58] Such delays may increase the likelihood of patients discontinuing reporting, potentially resulting in negative outcomes.[54,55] Several systematic literature studies have highlighted that the limitations of mHealth are linked to the absence of theoretical frameworks to guide design and evaluation.[56,57] The TB-TST content was developed based on the Information-Motivation-Behaviors Still Model. However, thoughtful implementation and continuous evaluation are essential to minimize drawbacks.

Similar to the original TB-TST tested in Argentina[34] and as documented in existing literature,[34,59,60] the most common barrier to app utilization for both participants and providers was internet access. Some participants lacked internet connectivity, and the clinic's poor network hindered nurses from promptly receiving and responding to reports. Most participants relied on pre-paid phones, which required data purchases for internet access, a financial challenge for individuals predominantly in the middle-low socioeconomic bracket, a significant social determinant of TB.[47]

Ideally, the app could improve the efficiency of nurse workflow, especially with the limited number of healthcare providers who can remotely monitor many patients.[60] However, the burden of using mHealth independently from the daily responsibilities has been identified as a significant barrier.[49] Despite our efforts to integrate the app into the treatment supporters' daily routines, it currently operates separately from the hospital system, which lacks electronic medical records and relies on paper-based charting. Integrating this app into the usual care with several scenario of reporting such as appointing a person to monitor the app besides the TB nurses is

crucial to ensure its effectiveness, especially considering the additional responsibilities it imposes on nurses who are already working beyond their capacity.

4.7 LIMITATIONS

Several limitations of this study should be noted. First, the use of a single-arm design was chosen due to time constraints. To mitigate this limitation, we compared treatment outcomes to historic rates to understand the initial impact of the intervention. Second, this study was conducted in the capital city, where internet connectivity is more robust. Although patients may come from surrounding or more rural settings, our results may not generalize to populations in other locations in Papua that are more rural and where digital literacy may differ.

4.8 CONCLUSION

The Samocare app provided a proven strategy to support individuals with TB that was found to be feasible, acceptable, and perceived useful. Both patients and treatment supporters emphasized the app's role in enhancing patient-centered care. Despite the variability in use, the app improved the monitoring system in the clinic, enabling the nurses to identify potential issues more effectively and increasing the likelihood of successful TB treatment completion. Additionally, the app supported data accuracy, which is critical for effective treatment management. Based on these finding, we propose that the Samocare intervention be refined and evaluated in a rigorous randomized controlled trial to evaluate the effectiveness on TB treatment outcomes, particularly in the context of Papua with its unique challenges and limited resources.

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Multimedia Appendix 4-1. Detail Samocare Application

Samocare is a Papua's adopted Tuberculosis Treatment Support Tools app. It is an interactive patient-provider digital adherence technology to monitor individuals with TB to finish their TB treatment linked with an easy-to-use home-based direct metabolite test to confirm adherence remotely. This App includes a patient and treatment supporter-facing mobile App. This App allows patients to report self-administration of their TB medication, track potential medication side effects, and upload a photo of a urine test to verify their adherence remotely. Additional features include access to accurate information about TB, alarm, set up and appointment reminder, a calendar view of their treatment progress, and the ability to communicate with a treatment supporter or anonymously with other patients in a group discussion forum. In addition to additional feature was added based on iteration: a daily change motivational behavior quote on the front page. For the provider interface, this App allows treatment supporters to monitor and provide necessary support for patients to finish the TB treatment. The home page has a cohort summary list of patients with issues that needed to be addressed that day, every patient profile to add patient information, track progress and priority, and add appointments linked to the patient's interface. Another feature includes a message feature to communicate with patients, monitor group discussions, and provide updated information or education to the group.

For the patient interface:

1. Home screen: medication report, side effect report, alarm, appointment, treatment milestone, test strip request, daily change motivational quotes.
2. Calendar: history of medication report and urine
3. A direct message to the healthcare providers and communication forum with no identification.
4. Information: Education content and tutorial for App and test strip

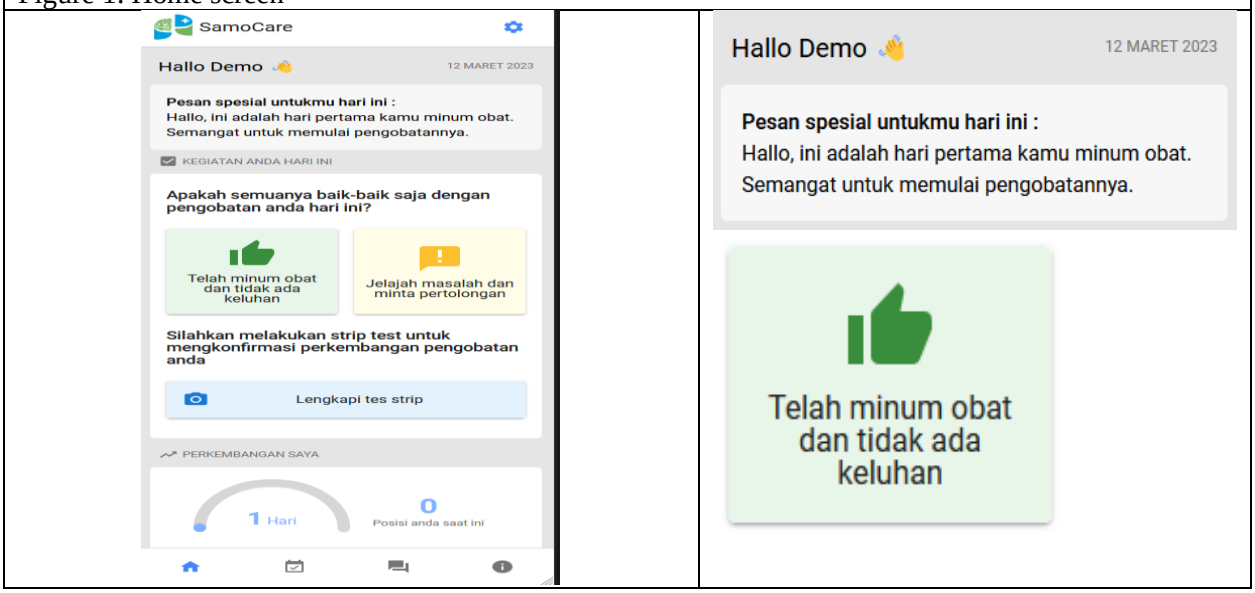
For the treatment supporter interface:

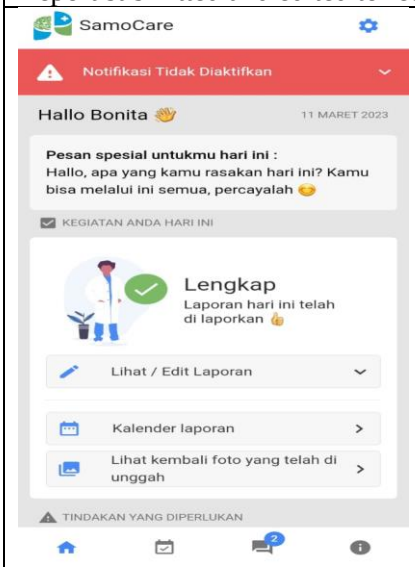
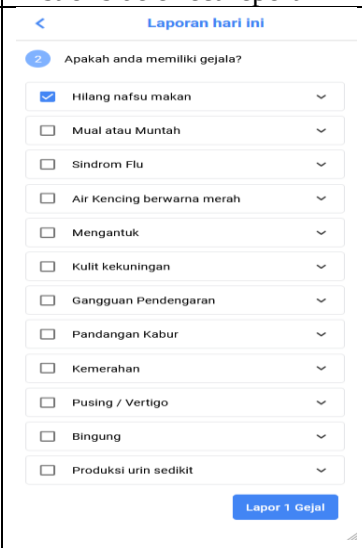
1. Home screen: List of all the patients with issues
2. Patient list: List of patients with detailed information and summary of the adherence percentage
3. Message: direct message for patient, group forum to monitor patients discussion, announcement.

Patient's interface app features and functions

The home page contains several functions for reporting medication features, alarm reminders, appointments list, treatment milestones, and daily motivation quotes

Figure 1. Home screen



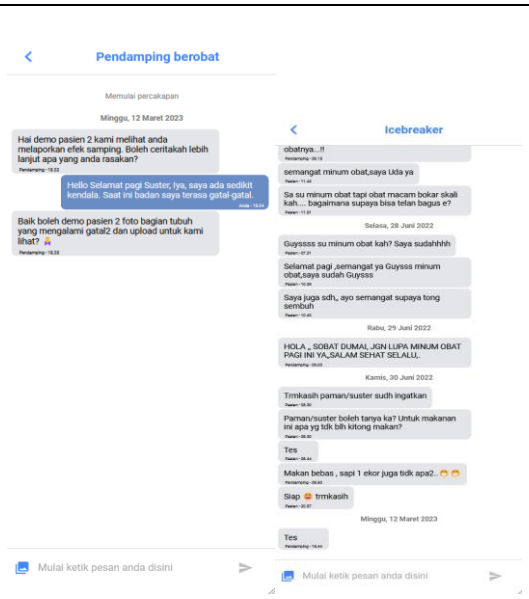
Report submitted and edited to request support	List of side effect report
	

Progress Page:
Track history of self-report TB medication intake with color-coded to see the medication intake, side effect report, and missed reporting in addition to tracking progress and treatment milestones.
Figure.3 treatment milestone and calendar (to record the medication intake activities

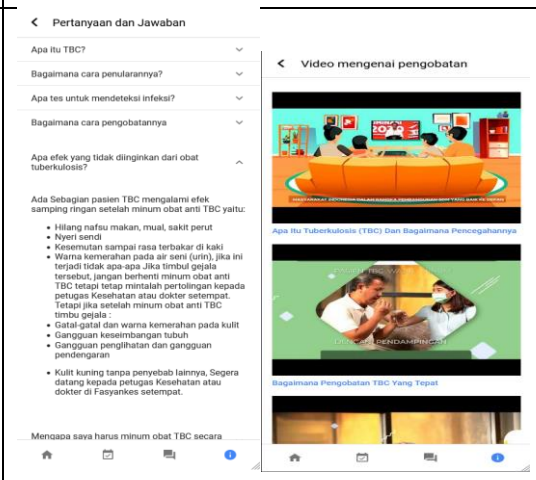
Figure.3 treatment milestone and calendar (to record the medication intake activities	
	

Message page: Features allow participants to communicate privately with the treatment supporter to improve support and motivation, in addition to group messages where participants can anonymously discuss their treatment experiences, questions, and issues with the app. Treatment supporters monitor the group discussion.

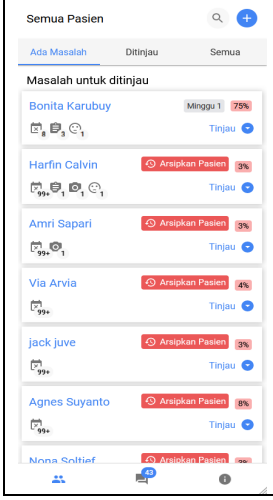
Figure 4. Message

Feature 4. Message	
	

Information page: contained two major pieces of information. First, regarding the disease and tips during the TB treatment (Education content). Second, about the app and how to take strip tests.
Figure 5. Education

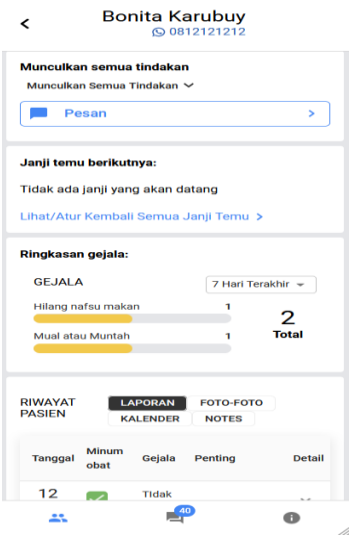
Figure 5. Education	
	

Section for Provider (Provider interface)
Home page: A summary cohort of clinic patients listed based on the priority issues.
Frontpage: summary of cohort and list patients based on the issues to resolve

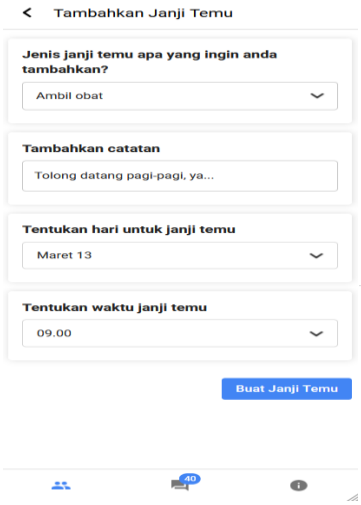
Frontpage: summary of cohort and list patients based on the issues to resolve	
	

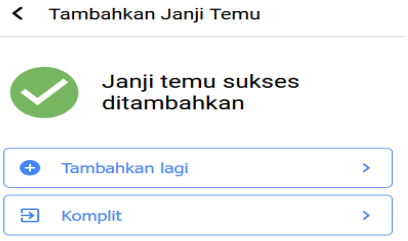
List of Patients profile:
The list of patients in the clinic and detailed profile contained all the information that treatment supporters can use to track progress and add appointments linked with the patient's side interface.

Patient's profile

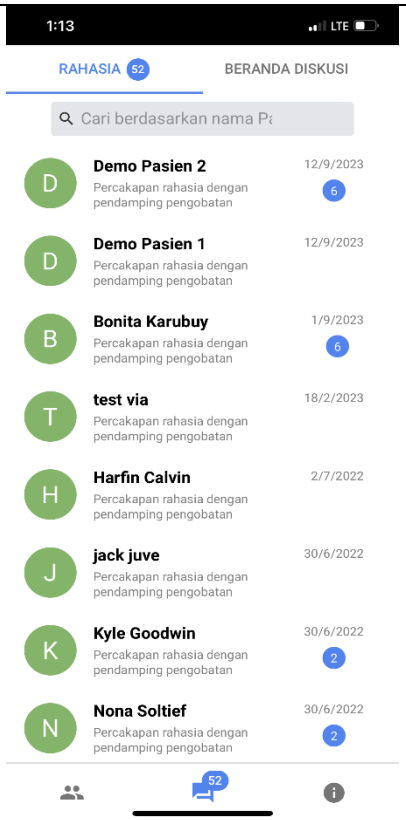


Appointment





Message:
Feature to facilitate communication between treatment supporter and patient where the patient can message privately about the issues and concerns during the treatment. In addition, there is a group discussion where the treatment supporter can monitor and control the discussion with a hiding feature to hide all the messages from the patients that are misleading or inappropriate. This feature is also used to announce if there is information that all patients need to know, for example, reminders about the holiday when the clinic will close or sending TB education.

Private message patient-treatment supporter	Group discussion and announcement.
	

Chapter 5. CONCLUSION

5.1 SYNOPSIS

This dissertation aimed to adapt, refine, and evaluate a patient-centered care intervention to support individuals with TB in Papua Indonesia. This region presents a unique dynamic population composed of a mixing of the indigenous and migrant populations. Indigenous cultures in Papua persist, consisting of diverse tribal groups historically underserved and marginalized in terms of healthcare access and resources.[1,2] We adapted and assessed a novel intervention to improve TB treatment success rates, aiming for long-term impact to improve overall health in Papua, which reports numerous poor health outcomes and substantial health disparities, particularly in infectious diseases. Notably, Papua has the highest prevalence of HIV, the highest incidence of malaria, and one of the highest rates of TB and lowest TB treatment success rates in Indonesia.[3] Given these challenges and disparities there is a need for patient-centered approaches to address these issues. Taken together, the evidence from this dissertation provides opportunities for healthcare services, clinicians, and researchers.

Chapter 2/Study 1 Summary

The first study aimed to identify TB-focused mobile applications available for Indonesian populations and evaluate their features and gaps. Our findings highlighted a lack of patient-centered applications that facilitate communication and collaboration between patients and providers or include strategies to verify treatment adherence. Additionally, none of the applications identified were tailored or tested for end-users in Papua.

Chapter 3/Study 2 Summary

In the second study, we aimed to address the gap identified in the first study by adapting and refining the TB-TST intervention to be culturally and contextually appropriate for a Papuan population and rebranding it Samocare. We conducted three rounds of iterative refinement of both the patient and treatment supporter interfaces. We completed field testing to enable the nurses to test the app workflow and identify potential problems prior to piloting in addition to develop a differential response protocol to respond to potential patient issues, such as missed daily reports and establish the number of text reminders before calling or scheduling a home visit.

Chapter 4/Study 3 Summary

The third study aimed to determine the usability, feasibility, acceptability, and initial impact of the Samocare intervention on TB care in Papua and identify areas for future improvement. We evaluated the Samocare intervention in a prospective one-arm pilot study within a real-world context and followed participants for six months. We collect data through usability questionnaires, exit surveys, interviews, app log data, and final treatment outcome. The findings suggested that the Samocare intervention was feasible, acceptable, and perceived as useful. Patients and treatment supporters reported that the application facilitated patient-centered care by improving communication and providing tailored support.

5.2 IMPLICATIONS FOR FUTURE RESEARCH

The collective studies presented here offer initial evidence that transforming TB care in Papua is feasible. This is the first study to employ Human-Centered Design (HCD) principles in rigorous, iterative, phased research activities involving individuals with TB, care providers, and design experts in Papua. Although the pilot test was successful, supporting the intervention as

useful, feasible, and accepted, it needs to be tested in a larger, adequately powered clinical trial. Further implementation research is necessary to evaluate the effectiveness and sustainability of improving TB care in Papua. The results from testing this technology to address healthcare challenges in Papua are critical, as they can serve as evidence and indicators of the adaptability of this innovative intervention to support TB care across Indonesia, particularly in resource-constrained and less developed areas.

If the intervention is successful in a larger trial, it could support Indonesia's digital health transformation, aligning with the health ministry's third priority activity of developing a health technology ecosystems by collaborating with government, research institute, industry and public.[4] With sufficient evidence, it is projected that by the time the Indonesia Health services (IHS) platform is ready (currently under development), this intervention can be integrated into the platform and adopted more widely in Indonesia to support the national TB program. Therefore, it is critical to continue testing and refining this intervention to ensure its effectiveness and that it complies with the Indonesia's regulation.

To continue this research trajectory, I present the proposed strategy using the domains from the WHO mHealth Assessment and Planning for Scale (MAPS) recommendations. MAPS is a self-assessment toolkit that is designed specifically for project managers and project teams who are already deploying an mHealth product, and who are aiming to increase the scale of impact.[5] The Samocare intervention relied on technology and access to the internet, it is crucial to recognize that not all areas in Papua currently have an adequate digital infrastructure.[6] Thus, the proposed strategy follows the domains outlined in the MAPS recommendations and is divided into strategies to consider for urban and rural areas.

Table 5-1. A proposed strategy in continuing the Samocare intervention in Papua based on the WHO MAPS domains.

Domain	Urban Papua	Rural Papua
Groundwork: the initial steps of specifying the key components of the projects approach to scaling up, assessing relevant contextual influences, and taking stock of the scientific basis for the product	Conduct pragmatic randomized control trial to obtain robust evidence supporting its effectiveness	Assess the intervention's adaptability to be modified, tailored, and refined to fit local context needs (enabling environment) Including a lower technology option such as texting or phone call report, using local community health worker to monitor TB patients and report to the treatment supporter using the app.
Partnership: collaborations with external groups to support the process of scaling up, including strategies for identifying, developing, and sustaining fruitful partnerships	- Continue the partnership with Papua's local government in Jayapura and expand partnership with several health departments of urban regencies across Papua. - Recruit healthcare providers from primary health clinics. - Involve community health workers (KADER)	- Reach out to local government to access readiness and support in implementing the intervention. - Partner with TB nurses to understand users' needs and priority to modify and tailor the intervention
Financial Health: The projection of scale-up costs, and the development of a financial plan for securing and	- Research funding competition from International and national sources. - Follow up suggestion from the meeting with stakeholders (March 13, 2023): integrate the program into Papua's regional	- Research funding competition from international and national sources. - Approach the local government for availability

managing funds over the long term	revenue and expenditure budget plan, emphasizing the potential benefits for local Papuans. - Approach the wireless network operator in Papua to gain support as part of their Corporate social responsibility (CSR) program. - Assess cost of intervention	of financial support from TB program budget.
Technology and architecture: Steps taken to optimize the mHealth product for scaling up based on its anticipated user base, purpose, integration with information systems and compatibility with other components of the information systems architecture	- Find strategy to mitigate barriers based on the pilot study data: • Ensure internet access for both individuals with TB and treatment supporters (inform the end-user: Individuals with TB the availability of offline report feature) • Facilitate smartphone ownership. - Partner with wireless network operator in Papua to improve access to the internet service or provide free data for utilizing the app. - Comply with Indonesia's regulation based on the blueprint digital health transformation 2024 such as	- Assess the technology readiness and what to modify in implementing the intervention such as: availability of internet access, smartphone users, community technology literacy

	assuring the available of health data integration and security.	
Operations: organizational and programmatic measures for supporting the implementation, use maintenance of the product throughout the scaling-up process	- Continue working with the healthcare providers as the treatment supporters in the TB clinics/primary health care services. - maintain partnership with local TB program implementers. - Conduct routine project evaluation	- Asses organizational readiness of change[7] from the local government - Comply with local regulation
Monitoring and evaluation: Decisions and activities that enable effective process monitoring and in-depth outcome evaluation, based on project and stakeholders need	Evaluate and report result of an RCT using Implementation research framework such as Consolidated Framework for Implementation Research (CFIR) or Research effectiveness adoption implementation and maintenance RE-AIM	Planning pilot study based on the assessment

With more rigorous research, this interactive digital adherence technology with the consideration of adaptation based on the local needs and resources availability, can be expanded to fulfill the four core functions recommended by the WHO Global Strategy on Digital Health for 2020-2025, specifically tailored for this purpose: 1) Person-centered care, 2) Program management, 3) Surveillance and monitoring, and 4) E-learning.[8]

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