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The role of digital health technology in tuberculosis control: a systematic literature review and comparative analysis based on the WHO guidelines

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Abstract

This study presents a systematic review with the objective of evaluating the utilisation of digital technology in the surveillance of Tuberculosis (TB) within the context of public health, and of determining the extent to which this practice aligns with the World Health Organization (WHO) recommendation. The methodology was divided into two distinct phases. In the initial phase, a systematic literature review was conducted utilising the Prism and the Parsifal tool. Subsequently, the digital technologies identified in the selected articles were analysed in accordance with WHO documentation and a patient-centred approach. From an initial pool of 2090 articles, nine studies were meticulously selected, including impactful research from regions such as India, China, Uganda, Sudan, Indonesia, Ukraine, Tanzania, South Africa an Philippines. These studies demonstrate that digital technologies have a beneficial impact. The digital technologies that have been highlighted as offering the most promising advancements in the field of TB surveillance, addressing existing challenges and integrating digital solutions seamlessly into TB control programmes, remain pivotal. In order to eradicate TB as a global health threat, future endeavours must focus on refining digital interventions, overcoming barriers and ensuring equitable access.

Keywords Tuberculosis · Public Health · Digital Health · Digital Technology · Mobile Applications

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1 Introduction

The 2022 WHO global report on TB indicates a worsening of the global situation [1]. While the mortality rate in Brazil appears to be relatively stable, with an average incidence of 2.1 deaths per 100,000 inhabitants, it remains a cause for concern. Notably, there are significant disparities in mortality rates across Brazil. One illustrative example is the city of Rio de Janeiro, which was established in 2022. The observed mortality rate was the highest among all Brazilian regions, reaching 4.4 deaths per 100,000 inhabitants [2].

TB has remained the second leading cause of death globally in 2022, with an estimated 1.30 million deaths, since the advent of the global pandemic. As indicated in the most recent WHO report, global TB targets have been either failed to be met or remain off track. The continued existence of undiagnosed or untreated TB, in addition to the presence of barriers to care, serve to impede the lowering of infection transmission rates. It is estimated that there is a global gap of 3.1 million deaths in 2022 between the estimated number of TB cases (incident cases) and the reported number of TB cases (notified cases) [3].

In the context of TB, there are several recommendations for engaging with research subjects in the field of public health. These recommendations include advocating for the integration of cutting-edge technologies and initiatives to enhance the management of TB [4]. With regard to standardised TB treatment protocols, direct observed therapy (DOT) is employed to reduce instances of treatment abandonment through the implementation of a monitoring system [5]. Video observed therapy (VOT) is frequently utilised in conjunction with mobile health (mHealth) solutions to facilitate remote medication consumption monitoring. [6].

In a global initiative to combat TB, the WHO developed a handbook for the utilisation of digital technologies to enhance TB medication adherence. This handbook provides guidance on the incorporation of diverse digital technologies into TB treatment efforts [7]. Mobile apps represent a promising avenue for leveraging digital technologies to enhance the efficacy of TB control programs. Despite the existence of numerous initiatives employing mobile technologies to facilitate the effective utilization of digital tools for TB management, a significant challenge persists, underscoring the necessity for a patient-centric approach [8].

The principal objective of this article is to address the following research questions through a systematic literature review, followed by a WHO digital recommendation and digital technologies focused analysis.:

1) How is research in digital technologies responding to challenges posed by TB?
2) How can the use of mobile apps improve the efficacy of TB surveillance in the public health domain?
3) Do these digital technologies meet the WHO Digital Health Interventions Guidelines?
4) Are these digital technologies focused on patient-centred approaches?

2 Methods

The methodology was divided into two stages. The first stage involved a systematic review using the Prisma method, with the objective of identifying articles that met previously established criteria. In the second stage, the selected articles were classified and compared in relation to WHO documentation and a patient-centred approach.

2.1 Systematic review using the Prisma method

Following an initial phase of discussion that started in October 2023, a multidisciplinary team comprising one researcher from computer science, another from digital health and the third from global health designed the protocol. The Prisma [9] and Parsifal tools [10], which facilitate the systematisation of identified findings from a literature review, were employed in this process.

Table 1 Keywords, Synonyms and Related to PICOC

Keywords	Synonyms	Related to (PICOC)
Digital System	App Application Digital Computing Digital Technology Mobile Software	Intervention
Tuberculosis in public health	Koch's Disease on public health Koch's Syndrome on public health TB on public health	Population

The three researchers involved in the literature review process discussed the keywords that should be addressed during a collaborative session. Subsequently, the research team selected two keywords, namely "digital system" and "tuberculosis on public health," to gain insight into the impact of digital systems on public health in the context of tuberculosis. These two keywords were recorded in the Parsifal tool, with the chosen synonyms and boundaries related to the Population, Intervention, Comparison, Outcome, and Context (PICOC) framework [10].

The keywords, synonyms and related to PICOC are presented in tabular form in Table 1. The initial search for the term "digital system" returned a list of synonyms, including "app," "application," "digital computing," "digital technology," "mobile," and "software." In the course of investigating the subject of "tuberculosis in public health," a number of alternative terms were identified, including "Koch's disease in public health," "Koch's syndrome in public health," and "TB in public health." In this context, the term "population" is defined as the total number of individuals within a given group or geographical area.

The subject of this study is the intervention, which is the use of digital systems, such as software, applications, digital technology, digital computing, apps, or mobile technology. The population affected by tuberculosis, such as Koch's Disease on Public Health, Koch's Syndrome on Public Health, or TB on Public Health, is also of interest. Table 2 presents the PICOC framework as conceived in the context of public health.

After defining the keywords, synonyms and PICOC, the research team discussed the exclusion and inclusion criteria using PICOC framework. The inclusion criteria according to PICOC were: Population (Tuberculosis, TB,Koch's Disease, Koch's Syndrome), Intervention (Digital system, Software, Application, Digital Technology, Digital Computing, App, Mobile), Comparison (Using Digital Technology) and Outcome (Using App at public health for TB monitoring) and Context (Public Health). The first exclusion criterion after the search is the exclusion of duplicate articles, then articles must be excluded according to the Picoc framework, that is, articles that are not about: Tuberculosis, digital intervention, public health. In regard to the scope of data utilized in the search, the analysis encompassed an examination of scientific articles from the most period of ten years, with adressed on a topic related to public health and having the minimum quality of being a scientific article in indexed journals. The Parsifal tool created the query:

("Tuberculosis on public health" OR "Koch's Disease on public health" OR "Koch's Syndrome on public health" OR "TB on public health") AND ("Digital system" OR "App" OR "Application" OR "Digital Computing" OR "Digital Technology" OR "Mobile" OR "Software").

The research team engaged in a discussion regarding the clarity and relevance of the Parsifal query in relation to the study questions. All members concurred, and the query was subsequently applied to the Scielo, Scopus, PubMed,. Ajol, and Web of Science databases for the purpose of locating academic articles.

This research study used the officially registered Open Science Framework (OSF)[1], and in the following section, present the results.

2.2 Classification and comparison in relation to WHO recommendations

In this second stage of the study, the selected articles were classified according to WHO objectives and classified according to Technology and support for the treatment that was to be carried out, based on the

Handbook for the Use of Digital Technologies to Support Tuberculosis Medication Adherence and a patient-centred approach, published by the WHO [7].

[1] https://osf.io/cdr8w

Table 2 PICOC framework

Population	Intervention	Comparison	Outcome	Context
Tuberculosis, TB, Koch's Disease, Koch's Syndrome	Digital system, Software, Application, Digital Technology, Digital Computing, App, Mobile	Using Digital Technology	Using App at public health for TB monitoring	Public Health

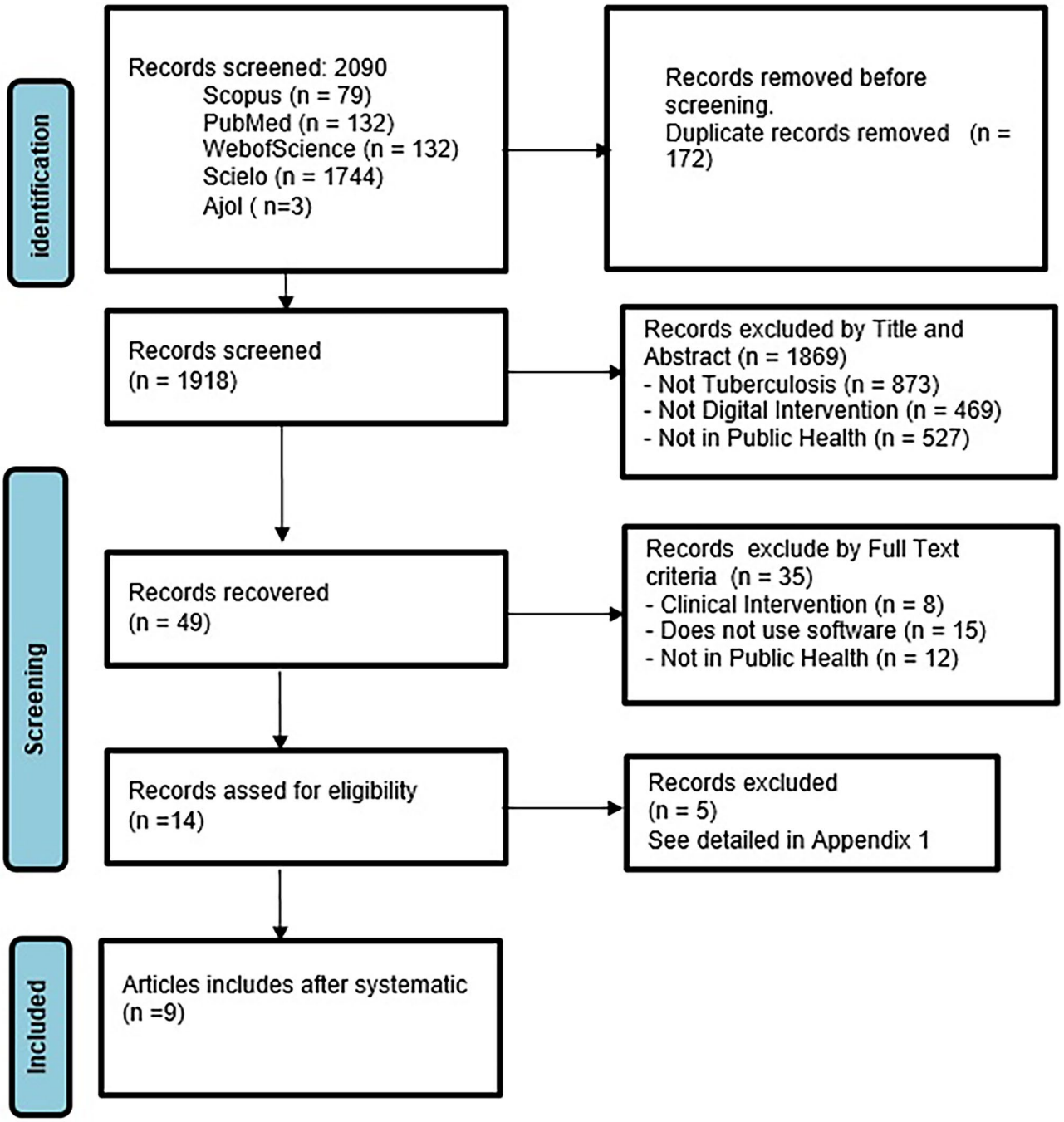

Fig. 1 Literature review findings systematized through a Prisma diagram [9]

3 Results

Figure 1 provides a comprehensive description of the methodology employed in the article selection process. The process was visualised using a Prisma diagram, which was divided into three stages.

The process comprises three stages: identification, screening, and inclusion, followed by exclusion and inclusion criteria for each stage. In the identification stage, the query yielded the following results in relevant databases: A total of 2090 articles were identified through Scopus (n = 79), PubMed (n = 132), Web of Science (n = 132), Scielo (n = 1744), and Ajol (n = 3). Following the removal of 172 duplicate articles, 1918 articles underwent screening. The

Table 3 Summary of selected articles

Reference	Article title	Type of study	Sample	Objective/Meth od	Study Results /Duration	Country
Navin et al. (2018) [11]	A mobile health intervention to support TB eradication program for adherence to treatment and a novel QR code-based technique to monitor patient–DOTS provider interaction	Pilot case study	20	Intervention study with a mobile application (TB Tracking) to verify the useof medication on a regularbasis through DOT and use the data collected for an analytical analysis	Through the use of the mobile ap- plication to check the regular use of medication and the symptoms. Allowing for bet- ter treatment monitoring. Duration: not availa- ble	India
Zhang et al. (2023) [12]	Digitizing tuberculosis treatment monitoring in Wuhan city, China, 2020–2021: Impact on medication adherence	Retrospecti ve cross- sectional study	1576	Comparative study of adherence to TB medication with app-based care with the paper-based standard of care	A higher success rate was found at the end of treatment Duration: 6 months	China
Byonaneby e et al. (2021) [13]	Impact of a mobile phone-based interactive voice response software on tuberculosis treatment outcomes in Uganda (CFL-TB): a protocol for a randomized controlled trial	Retrospecti ve cross-sectional study	274	This study seeks to determine the impact of the use of voice-based mobile applications on TB treatment success infivepublichealthfa cilitiesinUganda	The use of mobile phones is available solution for health systems in most low and middle income countries Duration: 6 months	Uganda
Park et al. (2021) [14]	Improving treatment adherence with integrated patient management for TB patients in Morocco	Interventio n	3605	This study aims to examine the TB management delivery model and the- outcomes of an in- tegrated patient management system with mobile health technology	It was observed that the use of the application was more effective than existing conventional programs. Duration: 2 years	Morocco
Ali et al. (2019) [15]	Mobile health to improve adherence to tuberculosis treatment in Khartoum state, Sudan	Controlled Pilot intervention	148	Pilot Study of controlled intervention in TB patients in a DOTS program using SMS to remember patient	The results were promising for reducing treat- ment dropout in TB patients us- ing mobile ser- vices. Duration:10 months	Sudan
Zhou et al. (2020) [16]	Digital tool assessment for the community management of patients with pulmonary tuberculosis in Yiwu city, China: evidence from real world data in 2020	Case Control Study	599	Multivariate logistic regression analysis revealed that the group using the digital tool had significantly better outcomes in terms of on-time completion of home visits, with an adjusted odds ratio of 0.41, highlighting the strong positive impact of the digital tool	Medication adherence for pulmonary TB patients in Yiwu city, China in 2020, showcasing potential for enhanced community management. Duration: 07 months	China

Table 3 (continued)

Reference	Article title	Type of study	Sample	Objective/Meth od	Study Results /Duration	Country
Paskaria et al. (2022) [17]	Digital Health to Strengthen District-Based Public–Private Mix Tuberculosis Control in Purwakarta District, Indonesia: A Qualitative Research	Qualitative	46	Purposive sampling technique for informants selection	It is concluded that the lack of communication between the public and the private health sectors in TB control was a major problem in DPPM TB. Duration 11 months	Indonesia
Jerene et al. (2023) [18]	Effectiveness of digital adherence technologies in improving tuberculosis treatment outcomes in four countries: a pragmatic cluster randomised trial protocol	Trials	NA	Pragmatic two-arm cluster-randomized trials were conducted across four countries, using health facilities as the unit of randomization. Facilities were randomly assigned to either the intervention group or the standard of care group	The effectiveness of digital adherence technologies in improving TB treatment outcomes is being evaluated. Study findings will be presented at both national and international conferences. Duration: 36 months	Ukraine, Tanzania, South Africa and the Philippines
Jonathan and Barakabitze (2023) [19]	SmartTB: An Innovative Digital Data-Driven Platform for Enhancing Tuberculosis Treatment Monitoring in Tanzania	Agile methodology	45	User acceptance testing confirmed the system's performance, showcasing its ability to effectively support TB patients' treatment monitoring and data management. The agile methodology was employed to gather requirements from three hospitals in Tanzania and to develop the system accordingly	This study demonstrated that SmartTB is an innovative approach that may enhance adherence to TB treatment. Patients can receive text message reminders on their scheduled day to visit the health facility for medication. Duration: N/A	Tanzania

total of 1918 articles obtained were excluded according to the Picoc Framework (not tuberculosis = 873, not digital intervention = 469, not public health = 527), resulting in the recovery of 49 articles.

Two independent computer science reviewers undertook an examination of the title, abstracts and keywords of the 49 articles in question. Following this process, 49 articles were determined to be ineligible on the grounds of meeting the exclusion criteria. Records exclude by full text reading (n = 35). The articles were grouped by the main reasons for exclusionin: Criteria Clinical Intervention (n = 8), does not use software (n = 15) and not in the context of public health (n = 12). The systematic review thus resulted in a final selection of 14 suitable articles, which were read in detail by both the independent reviewers and the research team. Appendix 1 contains a summary of the detailed reasons for exclusion in the last stage. Finally, only nine articles were deemed suitable for inclusion in the final analysis. Table 3 presents a summary of the nine selected articles.

The following section employs a narrative description, with the inclusion criterion referenced. The objective is to assist the scientific community in comprehending the principal contributions and the existing gaps that each study has sought to address.

1. Navin et al. [11]—This article presents evidence in support of the utilisation of a smartphone application designated as "TB Tracking." An Indian-developed system enables the real-time monitoring of symptoms during medication by sending SMS alerts to the DOTS provider while simultaneously recording the data in a database. It is beneficial to provide patients with instructional and encouraging messages, as well as reminders or alerts regarding drug consumption and upcoming medical tests throughout several phases of therapy. In this instance, QR code technology is employed to oversee the interaction between the patient and the DOTS provider during the course of treatment. Those who participated in the programme were furnished with crucial information pertaining to the illness, in addition to the option of remotely communicating their symptoms. The e-learning training was conducted with the objective of familiarising individuals with mobile phone technology, thereby enhancing their experience of using it.
2. Zhang et al. [12]—This study examines the impact of digitalisation on TB treatment and surveillance in the Chinese city of Wuhan between 2020 and 2021. The authors conducted a comparative analysis of two distinct approaches for monitoring TB medication adherence over a six-month period. The initial approach employed the electronic system, the E-Patient Service System (E-PSS). Secondly, a paper-based standard of care, the TB Control Information System (TCIS), was employed. A retrospective cross-sectional analysis was conducted on all patients diagnosed with drug-susceptible pulmonary TB, with data recorded in both systems. The primary metrics included the timely scheduling of the initial follow-up appointment (within three days of the commencement of treatment), the demonstration of medication adherence (defined as the consumption of at least 80% of the prescribed doses on a monthly basis), and the success rate at the conclusion of the therapeutic regimen. A total of 1,576 patients were included in the study, and the group that used E-PSS demonstrated a higher level of treatment adherence over the six-month treatment period.
3. Byonanebye et al. [13]—This article examined the impact of voice-based therapies in resource-constrained environments with a significant incidence of TB and high levels of illiteracy. The study was conducted at five public health institutions in Uganda. The existing software was adapted using a theory-based and human-centred design approach, resulting in the creation of a new software package, entitled "Call for Life-TB". This mobile health intervention employs interactive voice response technology to facilitate medication adherence reminders and appointment scheduling, while enabling remote symptom reporting. A total of 274 individuals were randomly assigned to a 1:1 ratio to each control group, who received standard care and retention services. The intervention group, on the other hand, received additional support, including improved adherence to TB medications, appointment reminders, and health recommendations. Following a six-month enrollment period, multivariable regression models were utilized to compare the efficacy of the therapy, adherence to treatment and clinical visits, and completion of treatment.
4. Park et al. [14]—The objective of this study was to examine the delivery model of TB management and the outcomes of an integrated patient management system that employs a patient-centred and community-based strategy in conjunction with mobile health technology. From January 2018 to December 2019, a programme was implemented in five regions of Morocco (Rabat, Salé, Kénitra, Khemisset, and Skhirat–Témara) and a total of 3605 individuals with TB were recruited. Patients were classified and treated according to a number of demographic, socioeconomic, geographical, health literacy and proximity-related factors. The mobile health solution, designated the "smart pillbox," was implemented among TB patients exhibiting elevated risk profiles, in conjunction with the provision of patient education. The success rate of the therapy was 92.2%, which exceeded the national average of 88%. The proportion of participants who were lost to follow-up was 4.1%, which was considerably lower than the 7.9% of participants

who failed to adhere to the study protocol. Therefore, the implementation of integrated patient management for TB patients in Morocco proved to be more effective than the existing programmes.

5. Ali and Martin H. Prins [15]—This article presents the findings of a study that sought to analyse the impact of utilising a mobile phone in the treatment of TB in Sudan. The study was conducted between 1 May 2017 and 31 March 2018. Eight medical treatment facilities participated in the study. The study employed a quasi-experimental design, with participants randomly assigned to either a text message reminder group or a control group. The text message group received daily reminders on their mobile devices to adhere to their prescribed treatment schedule, while the control group did not receive any such messages. The study sample consisted of 148 individuals, with 74 individuals in each group. The data analysis revealed that the text message group exhibited a higher proportion of favourable treatment outcomes and a greater level of patient acceptability.
6. Zhou et al. [16]—The objective of this study was to ascertain whether digital tools could be utilised to enhance the punctuality of home visits in Yiwu City. The findings indicated that digital tools had a favourable impact on the punctuality of home visits. The methodology employed involved a comparison between the routine group and the digital tool group, with the use of multivariate logistic regression analysis to ascertain the on-time completion status. The findings suggest that digital tools enhanced medication adherence rates in comparison to the control group.
7. Paskaria et al. [17]—This study examines the challenges encountered in district-based public–private mix TB (DPPM TB) in Purwakarta district and considers the potential role of digital health in addressing these issues. A qualitative research design was employed, comprising interviews with 46 informants and focus group discussions with nine participants, conducted between January and November 2020. The principal issues that have been identified include deficiencies in communication, an under-reporting of TB cases in the private sector, and the constraints of the current information system. The study concludes that the improvement of communication through digital health solutions is a vital component in the effective control of TB between the public and private health sectors.
8. Jerene et al.[18]—The objective of this paper is to evaluate whether the implementation of digital adherence technologies (DATs) with daily monitoring and a differentiated response to patient adherence would result in a reduction in poor treatment outcomes when compared with the standard of care (SOC). The trial was conducted in four high-burden TB countries, selected based on a range of epidemiological and health system factors. The facilities included in the study comprise a combination of urban and rural settings, thereby ensuring a comprehensive evaluation of DAT implementation. The study is designed to reflect real-world conditions by including a diverse range of health facilities. In order to be eligible for inclusion in the study, facilities must have previously notified TB patients and be willing to participate. The findings of the study will be disseminated at national and international meetings.
9. Jonathan and Barakabitze [19]—This article examines the utilisation of SmartTB software to facilitate TB medication adherence through Directly Observed Therapy (DOT) in three hospitals in Tanzania. It provides an account of the evolution of the application and emphasises its favourable reception and utilisation, as evidenced by feedback from a range of healthcare professionals.

The Themes and Areas resulting from each article were summarized in Table 4.

Table 4 shows that the themes relating to the monitoring of patients with DOT can be seen in the articles by Navin et al. [11], Ali et al. [15] and Jonathan and Barakabitze [19]. Zhang et al. [12] addresses the topic of Digitalization the TB treatment, Byonaneby et al. [13] studies the a mobile phone-based interactive voice response software, Seup et al. [14] the patient management system with mobile health technology, Zhou et al. the Digital tool assessment for the community management of patients, Paskaria et al. [17] the integrated patient management system with mobile health technology for Public–Private communication, Jerene et al. [18] the effectiveness of DAT in TB treatment. The area resulting from the articles was impact on medication adherence in the articles Navin et al. [11], Zhang et al. [12], Byonanebye et al. [13], Ali et al. [15], Zhou et al. [16], Jerene et al. [18]. The resulting area of disease management in health centers was addressed by Park et al. [14] and Paskaria et al. [17].

3.1 WHO digital health interventions and support tuberculosis medication adherence

The World Health Organization's Classification of Digital Interventions, Services, and Applications in Health [20] is a useful tool for stakeholders in the technology and healthcare sectors, providing them with a common language and a structured framework for discussing and planning health interventions. The document presents a taxonomy for categorizing digital interventions in healthcare that can be divided into three axes: (1) health system challenges, (2) digital health interventions (DHIs), and (3) types of digital services and applications. One of these three taxonomies, DHIs, is

Table 4 Themes and Resultant Area of selected articles

Reference	Themes	Resultant Area
Navin et al.(2018) [11]	Monitor patient–DOTS	Impact on medication adherence
Zhang et al. (2023) [12]	Digitalization the tuberculosis treatment	Impact on medication adherence
Byonaneby e et al. (2021) [13]	Impact of a mobile phone-based interactive voice response software	Impact on medication adherence
Park et al. (2021) [14]	Integrated patient management system with mobile health technology	Impact on disease management in health centers
Ali et al. (2019) [15]	Monitor patient–DOTS	Impact on medication adherence
Zhou et al. (2020) [16]	Digital tool assessment for the community management of patients	Impact on medication adherence
Paskaria et al. (2022) [17]	Integrated patient management system with mobile health technology	Impact on disease management in health centers
Jerene et al. (2023) [18]	Effectiveness of DAT in tuberculosis treatment	Impact on medication adherence
Jonathan and Barakabitze (2023) [19]	Monitor patient–DOTS	Impact on medication adherence

Table 5 WHO digital technology classification

WHO–Classification of digital interventions [20]	WHO–Digital technologies to support tuberculosis medication adherence [7]	Selected articles
Person	Patient care	Navin et al. (2018) [11] Byonanebye et al. (2021)[13] Aliet al. (2019) [15] Zhou et al. (2022)[16] Jerene et al. (2023) [18] Jonathan and Barakabitze (2023) [19]
	E-learning	Navin et al.(2018)[11]
Health Care Provider	Surveillance and monitoring	Zhang et al. (2023)[12] Park et al. (2021)[14] Paskaria et al. (2022) [17]
Health Management and Data Service	Program management	Zhang et al. (2023)[12] Park et al. (2021)[14]

also divided into four categories: (2.1) DHIs for persons, referring to interventions involving patients, including health prevention and wellness activities; (2.2) DHIs for healthcare providers, focusing on the healthcare workforce; (2.3) DHIs for health management and support personnel, encompassing administrative healthcare services; and (2.4) DHIs for data services, involving data management and governance services.

The World Health Organization's Handbook for the Use of Digital Technologies to Support Tuberculosis Medication Adherence [7], classified digital technologies into TB treatment efforts related to: Patient care, surveillance and monitoring, program management and e-learning. The selected articles were classified according to WHO in Table 5

Table 5 presents a classification of articles in accordance with the World Health Organization (WHO) framework for digital technology. In accordance with the WHO Medical Adherence Treatment Effort. The studies conducted by Zhang et al. [12] and Park et al. [14] were classified under the categories of "Program Management" and "Surveillance and Monitoring," respectively. In terms of the WHO Digital Health Intervention, the articles are classified as either "Health Care Provider" or "Health Management and Data Service". The articles from Navin et al. [11], Byonanebye et al. [13], Ali et al. [15], Zhou et al. [16], Jonathan and Barakabitze [19] and Jerene et al. [18] are classified under the heading of "Patient care". The article by Navin et al. [11] was additionally classified as "E-Learning".

3.2 Addressing a Person-centered approach in TB context

It is crucial to develop digital interventions that are grounded in a person-centred approach, which considers the nuances of low digital literacy, the social context, and demographic factors. A person-centred approach addresses the needs of both the patient and the healthcare provider. It is essential that both parties incorporate and evaluate their impressions of the usage, as well as identify any limitations that may impact their everyday activities (access barriers). In terms of financial and temporal implications, patients may be affected by factors such as stigma risk, health and digital health literacy, and technological maturity. In addition, healthcare professionals must consider the time investment, cost implications, digital health literacy, technological maturity, reliability and maintenance, and process change coordination [21] involved. As illustrated in Table 5, studies by Navin et al. [11], Byonanebye et al. [13], Ali et al. [15], and Zhou et al. [2] In addition, Jonathan and Barakabitze [19] and Jerene et al. [18] present a person-centred approach in accordance with the WHO Digital Health Intervention.

The selected articles demonstrate the significant impact of mobile applications and text reminders on treatment adherence, patient outcomes, and symptom monitoring in diverse cultural contexts, including India, Uganda, and Sudan. The mobile application serves to facilitate traditional approaches, such as directly observed therapy (DOT), and includes the incorporation of basic electronic communication standards, such as the use of SMS reminders for the purposes of medication adherence. Furthermore, they have demonstrated outcomes that are promising in terms of improving levels of engagement and treatment success rates. It is noteworthy that the integration of the e-learning objective in Navin et al. 's study [11] demonstrates the potential for comprehensive digital solutions to incorporate educational components, thereby promoting patient understanding and engagement throughout the treatment process.

This article identifies several promising solutions for the control of TB through digital interventions that have the potential to transform healthcare. Nevertheless, certain constraints were discerned in the selected articles where interventions were conducted in low-income countries. These included the reality that not all individuals have access to digital technologies or the internet, particularly in rural, low-income, or elderly populations. The high

costs associated with these interventions may act as a barrier to access, particularly for individuals with limited financial resources or lacking comprehensive insurance coverage.

4 Conclusion

The objective of the systematic literature review conducted in this study was first to examine the role of mobile technologies and mobile applications in enhancing TB surveillance within the context of public health, and secondly, to ascertain whether these technologies are aligned with specific WHO guidelines. The findings from the review, comprising nine selected articles, provide insights into the utilisation of digital systems in TB management and surveillance across multiple regions, emphasising their potential impact on treatment adherence, patient monitoring and healthcare delivery.

In alignment with the WHO guidelines on digital health interventions, the reviewed studies predominantly focused on patient-centric interventions, underscoring the significance of patient empowerment and the effective management of health data through digital platforms. However, the implementation of digital technologies for TB management is confronted with a number of challenges, including digital health literacy, technological barriers, access constraints, and maintenance issues. It is therefore imperative that these challenges are addressed in order to ensure the equitable and sustainable deployment of digital tools, particularly in resource-constrained settings.

The prospect of enhancing the standard of care for those with TB, advancing research, and fostering collective action hinges on surmounting obstacles, refining interventions, and guaranteeing the seamless integration of digital technologies into TB control programmes. It is of the utmost importance to address these challenges in a person-centred context. This approach signifies that healthcare providers are contemplating the potential for global efforts to advance towards the eradication of TB as a public health threat.

However, despite the encouraging outcomes observed in these selected studies, significant challenges and constraints remain in the implementation of digital technologies for the management of TB. The evaluation of these interventions revealed a number of issues, including digital health literacy, technological barriers, access constraints, costs and maintenance concerns. It is also noteworthy that only six of the selected articles addressed patient-centred procedures, despite the acknowledged challenges in the use of technology by healthcare providers.

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Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

Appendix 1: List of articles excluded in the last stage (see Table 6)

Table 6 Articles Excluded in the last stage

References	Title	Reasons for exclusion
Sazali et al. (2022)[21]	Improving Tuberculosis Medication Ad- herence: The Potential of Integrating Digital Technology and Health Belief Model	This is not an article on software application for Healthcare. It is a review article To describe the concepts and the HB M Treatment Mode
Mantas et al. [22]	Development of a Mobile Application with Health Guidelines for TB Patients Care	The objective of the study is to develop a guide for healthcare professionals on the Treatment of TB
Getachew, Woldemanuel, Man-yazewal, (2022) [23]	Digital health interventions in the clinical care and treatment oft tuber- culosis and hiv in central Ethiopia: An initial provider perceptions and acceptability study using the unified theory of acceptance and use of tech-nology model	The objective of the article is to understand which factors depend on the acceptance of Technology
KigubaR, Mweba-za, Ssenyonga et al. [24]	EffectivenessoftheMedSafetymobileappli-cationinimprovingadversedrugreaction re- porting by healthcare professionals in Uganda: a protocol for a pragmatic clus- ter randomised controlled tri	The research addresses adherence to treatment for patients with HIV and not for TB
Ferreira et al. 2020 [25]	Tuberculosis control: assessment of an ap- plication for primary care	This study addresses an evaluation for building an application for TB

The data are provided within the manuscript or supplementary information files (Appendix 1). The raw data of this study are available from the corresponding author upon reasonable request

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