Patient Preference and Adherence

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REVIEW

# Effectiveness of Digital Health Interventions to Enhance Continuity of Care in Patients with Pulmonary Tuberculosis: A Systematic Review of Randomized Controlled Trials

Qonita Nur Miladi[1], Tuti Pahria[2], Iqbal Pramukti[3]

[1]Master Study Program, Faculty of Nursing, Universitas Padjadjaran, Sumedang, West Java, Indonesia; [2]Department of Medical-Surgical Nursing, Faculty of Nursing, Universitas Padjadjaran, Sumedang, West Java, Indonesia; [3]Department of Community Health Nursing, Faculty of Nursing, Universitas Padjadjaran, Sumedang, West Java, Indonesia

Correspondence: Tuti Pahria, Faculty of Nursing, Universitas Padjadjaran, Jl. Raya Ir. Soekarno KM. 21, Hegarmanah, Jatinangor, Sumedang, West Java, 45363, Indonesia, Fax +62228779341l, Email tuti.pahria@unpad.ac.id



**Background:** Pulmonary tuberculosis (TB) remains a global health concern with high morbidity and mortality rates. Despite being curable with proper treatment, challenges in ensuring continuity of care persist, particularly in resource-limited settings. Digital health interventions (DHI) offer a potential solution to improve treatment adherence and continuity of care among TB patients.

**Purpose:** This study aimed to systematically review how DHIs contribute to improved continuity of care, particularly in terms of medication adherence, clinical outcomes, and patient satisfaction.

**Methods:** A systematic review was conducted using PRISMA guidelines. Relevant studies were identified from five significant databases, including PubMed, Scopus, Taylor and Francis, EBSCO-host, and ScienceDirect, up to November 2024 and one search engine was Google Scholar. The keywords used were "pulmonary tuberculosis OR tbc OR tb AND mobile health applications OR mhealth OR mobile apps OR telehealth AND continuity of care OR patient compliance OR patient adherence OR adherence behaviour. Inclusion criteria focused on RCTs evaluating DHIs for adult TB patients. Data were extracted and analyzed thematically to assess intervention effectiveness on medication adherence and clinical outcomes.

**Results:** A total of 17.380 patients from 21 studies TB patients were included. Interventions were classified into two categories: reminder-based (eg, SMS, phone calls, electronic medicine boxes with audio/visual alerts) and remote monitoring-based (eg, MERM, mobile applications, digital sensors, and VDOT). Compared to standard care, DHIs significantly improved medication adherence, treatment success rates, and patient satisfaction. Several studies also reported reduced time and cost burdens for patients.

**Conclusion:** DHIs improve continuity of care among TB patients by increasing medication adherence and clinical outcomes. However, the effectiveness varies across different intervention types and settings, emphasizing the need for tailored strategies and integration into existing health systems.

**Keywords:** adherence, continuity of care, digital health interventions, pulmonary tuberculosis, randomized controlled trials

## Introduction

Pulmonary tuberculosis (pulmonary TB) remains a significant global health problem, with high morbidity and mortality rates. According to the 2024 WHO Global Tuberculosis Report, tuberculosis (TB) regained its position as the leading cause of death from infectious diseases in 2023, with an estimated 1.25 million deaths globally, nearly double the number of fatalities caused by HIV/AIDS in the same year.[1] Although TB is curable with appropriate treatment, ensuring continuity of care remains a significant challenge in TB control efforts, especially in low-resource settings where consistent access to treatment and long-term patient monitoring may be limited.[2]

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The increase in mortality rates in TB patients is in line with problems related to treatment compliance, lack of information, and poor continuity of care.[3,4] Continuity of care is a critical aspect of TB treatment because incomplete treatment can lead to therapy failure, drug resistance, and increased risk of transmission.[5] Continuity of care in TB management includes interrelated aspects, such as patient-health-worker relations, information management, treatment compliance, service accessibility, psychosocial support, effective communication, and ongoing monitoring.[6,7] All these elements contribute to TB therapy's success and drug resistance prevention. To overcome these challenges, various technology-based innovations have been introduced.[8]

In recent years, digital health interventions (DHI) have emerged as a potential solution to improve treatment adherence in TB patients.[9] DHI encompasses a variety of technologies such as text messaging (SMS), mobile applications, and video-observed therapy (VOT) designed to facilitate communication between patients and healthcare providers.[10–13] In addition, smart pillboxes, or AI-powered monitoring tools have also been developed to support medication adherence by providing real-time tracking and automated reminders.[14–19] These technologies aim to enhance patient engagement, enable timely interventions by healthcare workers, and ultimately improve treatment outcomes in TB care. Research shows that the use of digital technologies can increase accessibility of care, improve communication between patients and healthcare providers, and provide reminders to take medications.[11,12,16]

DHIs hold substantial promise in enhancing continuity of care for TB patients, particularly by improving medication adherence, enabling remote monitoring, and facilitating communication between patients and healthcare providers. Despite this potential, evidence regarding their effectiveness remains inconclusive. While some studies have demonstrated favorable outcomes for example, increased adherence associated with smartphone-based applications in TB patients in India.[20] Other findings indicate that such interventions may have limited impact in the absence of sufficient health system support.[21] Notably, the effectiveness of DHIs in sustaining continuity of care in TB treatment has not yet been comprehensively evaluated through robust, evidence-based methodologies.

Based on the results of the literature search, no systematic review has specifically synthesized evidence from RCTs on how DHIs support continuity of care in a comprehensive manner not only in terms of medication adherence, but also encompassing aspects such as provider-patient communication and remote monitoring. Previous studies on the same topic were only scoping reviews and were limited to medical adherence, and the articles analyzed were heterogeneous and did not focus on RCT design.[9,22] In addition, previous studies primarily focuses on the aspect of medical adherence without exploring broader aspects of continuity of care, such as communication between patients and health workers, ongoing monitoring, and service integration.[23]

From these problems, a new, more targeted systematic review, including only RCTs, is needed to evaluate the effectiveness of DHI on continuity of care as a whole. This review is expected to provide a more specific understanding of the impact of DHI on continuity of care, produce scientific novelty with an in-depth analysis of continuity of care, and provide evidence-based guidance for policy development and clinical practice, especially in the context of implementing digital technology to support global TB elimination.

# Materials and Methods

## Study Design

This literature review uses a systematic review design. This study uses the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.[24] This review protocol has not been registered in any database.

## Eligibility Criteria

This study's research question and eligibility criteria used the PICOT (population/intervention/ comparator(s)/outcomes/ type of study) approach. The inclusion criteria of the articles analyzed in this review were experimental studies published in full-text in English until November 2024. In addition, the studies must discuss digital health interventions on continuity of care in pulmonary tuberculosis patients, and there is no limitation to the year of publication in the selection of articles. In this review, the authors excluded protocols, studies in languages other than English as the international language, and full-text publications that are not accessible. The following is an explanation of the PICOT applied in this review.

Population: Adult patients with tuberculosis
Intervention: Digital health intervention or Mobile health
Comparator: Usual care or Standard care
Outcomes: Continuity of care (Medication adherence, clinical outcome, patient satisfaction, etc)
Type of Study: Randomized controlled trial

## Data Collection and Analysis

### Search Strategy

Two independently reviewers conducted a systematic literature search by one author (Q.N.M and I.P) using five major databases: EBSCO-host, PubMed, ScienceDirect, Scopus, Taylor and Francis, and one search engine, Google Scholar. We used Boolean operators "OR" and "AND" in the literature search to help us find articles. The keywords used were "pulmonary tuberculosis OR tbc OR tb AND mobile health applications OR mhealth OR mobile apps OR telehealth AND continuity of care OR patient compliance OR patient adherence OR adherence behaviour". For each term verified by MeSH (Medical Subject Headings), synonyms are used to retrieve all possible relevant articles. In addition, the author uses the Boolean operators "AND" and "OR" to trim or expand the search results for various tenses. More details can be seen in Table S1.

### Study Selection and Quality Appraisal

Two independent authors (Q.N.M and I.P) selected studies that met the eligibility criteria. The authors checked for duplication in the initial stage using Mendeley's reference manager. Then, they continued to check the title, abstract, and full text for relevance to the research topic and inclusion and exclusion criteria. In the final process, all authors (Q.N.M, I. P, and T.P) checked each full text with the Joanna Briggs Institute (JBI) critical appraisal checklist, and then the JBI assessment results were compared.[25] There are 13 statements for articles with randomized control trial designs.

Specifically, we calculated the critical appraisal score as the number of "yes" responses divided by the total number of "unclear", "no", and "yes" responses, excluding "no information" responses. After the assessment, we eliminated all studies with a JBI score of <70%. Furthermore, all authors discussed and decided whether there were any discrepancies in the election results. All authors had no differences of opinion regarding the selection and eligibility of the studies analyzed in this study.

## Assessment of Risk of Bias in Included Studies

Two reviewer (Q.N.M and I.P) independently assessed the Risk of Bias (RoB) for RCT studies included in this review analysis using the Cochrane Risk of Bias (RoB) tool. RCT studies consist of five RoB domains, including (1) randomization process, (2) deviation from the intended intervention, (3) missing outcome data, (4) outcome measurement, and (5) selection of reported outcomes.[26] RoB is defined as "high", "low", or "some concern", or "no information" for each domain.

### Data Extraction and Analysis

Data were extracted using an extraction table by one reviewer (Q.N.M) and checked by other reviewers (I.P and T.P). At this stage, the authors extracted data from articles that met the criteria where we collected information related to the characteristics of each study: study, design, country, sample size, intervention, comparison, results, and JBI assessment results.

This review conducted data analysis thematically and qualitatively using exploratory and descriptive approaches. The data analysis process began by identifying and presenting the data obtained in tabular form based on the articles reviewed. After obtaining the data, all authors analyzed and presented the results of each study, which focused on exploring how technology can contribute to improving ongoing and long-term care for tuberculosis patients.

# Results

## Study Selection

The study selection process was done through several systematic stages to ensure that only relevant and high-quality articles were analyzed (see Figure 1). The first stage is identification, where 2,926 articles were taken from five major

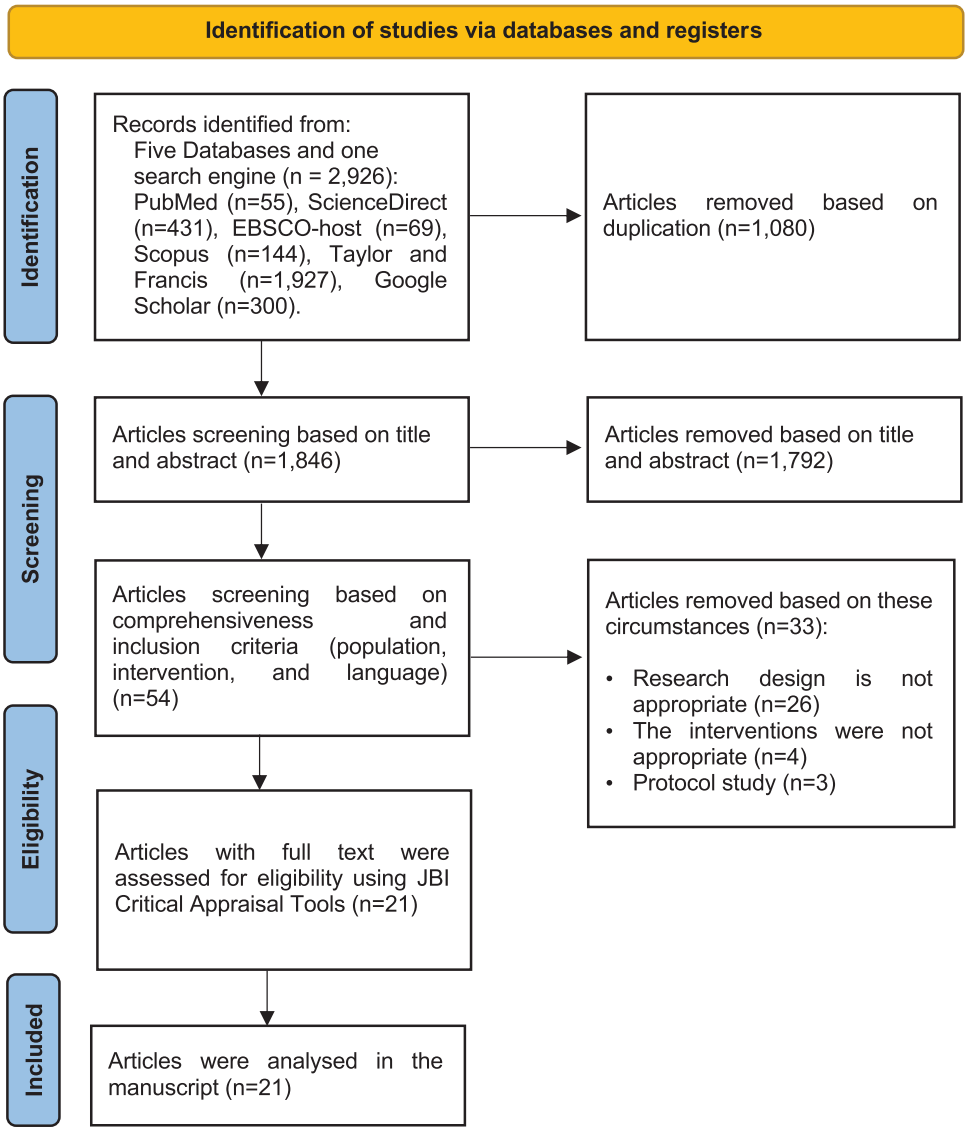


**Figure 1** PRISMA Flow Diagram. Adapted from Page MJ, McKenzie JE, Bossuyt PM et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021; 372: n71. Creative Commons.[24]

databases, including PubMed, ScienceDirect, EBSCO-host, Scopus, Taylor and Francis, and one search engine, Google Scholar. After removing 1080 duplicate articles, 1,846 were selected based on title and abstract. At this stage, 1,792 articles were eliminated because they were not relevant to the focus of the study.

Next, 54 articles were screened for completeness, population, intervention, and language, resulting in 33 articles that did not meet the criteria (26 articles with inappropriate study designs, 4 articles with irrelevant interventions, and 3 protocol studies). 21 eligible articles were assessed using the JBI (Joanna Briggs Institute) critical appraisal tool and included in the final analysis of the manuscript. This selection process ensured that only relevant, valid, and high-quality articles were analyzed further.

## Characteristics of the Included Studies

Table 1 describes the characteristics of the studies analyzed in the systematic review, showing variations in country of origin, sample size, type of intervention, comparison method, and outcomes achieved. The total sample of the studies analyzed was 17.380 patients from 21 studies. All studies analyzed were RCT-based studies with participants from

**Table 1** Characteristics of Study

| Study | Design | Country | Sample Size | Intervention | Comparison | Results |
|---|---|---|---|---|---|---|
| Mohammed et al (2016)[10] | RCT | Pakistan | 2207 TB patients, IG (n=1100); CG (n=1107) | Daily SMS reminders (Zindagi SMS) | Control group (no SMS) | No significant difference in treatment success or adherence rates between SMS reminder and control groups. |
| Bediang et al (2018)[11] | RCT | Cameroon | 279 TB patients, IG (n=137); CG (n=142) | Daily SMS reminders in addition to usual treatment | Control group (usual treatment only) | • There was no difference in outcomes between the intervention and control groups.<br>• 6-month follow-up: 111 successful treatments (81%) in the intervention group and 106 (74.6%) in the control group.<br>• The number of drop-outs at 6 months was 47 (34.3%) in the intervention group and 46 (32.4%) in the control group. |
| Khachadourian et al (2020)[27] | Cluster Randomized Trial | Armenia | 385 TB patients in 52 clusters, IG (n=187); CG (n=198) | Self-administered drug intake supported by family member | Clinic-based DOT | • Self-administered care with family support showed non-inferior treatment success to clinic-based DOT, with improved adherence.<br>• Treatment success of 92.0% (IG) and 92.9% (CG).<br>• Knowledge, depression, stigma, quality of life, and social support also showed non-inferiority, showing substantial improvement over time. |
| Kunawararak et al (2011)[28] | RCT | Thailand | 230 TB patients, IG (n=115); CG (n=115) | Phone call reminder added to conventional DOTS | Conventional DOTS only | **Sputum Conversion Rates**:<br>• In multidrug-resistant TB (MDR-TB) patients, the sputum conversion rate at 1 month was significantly higher in Model 2 (90%) compared to Model 1 (20%) ($p<0.001$).<br>• In non-MDR-TB patients, the sputum conversion rates were 37% (Model 2) and 52% (Model 1), but the difference was not statistically significant ($p=0.221$).<br>**Treatment Success Rates**:<br>• In MDR-TB patients, success rates were significantly higher in Model 2 (100%) compared to Model 1 (73.7%) ($p<0.001$).<br>• For non-MDR-TB patients, Model 2 also showed higher success rates (100%) compared to Model 1 (96.7%) ($p=0.047$).<br>**Reduction in MDR-TB Incidence**:<br>• MDR-TB incidence in northern Thailand decreased from 4.1% (April–September 2008) to 1.8% (April–September 2009), coinciding with the implementation of mobile phone reminders. |
| Ravenscroft et al (2020)[29] | RCT | Moldova | 197 TB patients, IG (n=98); CG (n=99) | Video Observed Therapy (VOT) | In-person DOT | VOT led to better adherence, decreased non-adherence by 4 days per two-week period, reduced time and costs for patient ($p<0,01$). |
| Bao et al (2022)[12] | RCT | China | 112 TB patients, IG (n=59); CG (n=53) | WeChat-based mHealth intervention | Routine care without WeChat intervention | Significant increase in self-management behaviors ($p<0,001$), TB knowledge, and adherence in WeChat intervention group ($p<0,001$). |
| Burzynski et al (2022)[30] | A Randomized Noninferiority Trial | USA | 216 TB patients, IG (n=113); CG (n=103) | Electronic DOT (video conferencing or recorded videos) | In-person DOT | • Electronic DOT was non-inferior to in-person DOT in adherence rates, with high satisfaction from patients using electronic methods.<br>• The percentage of completed doses with face-to-face DOT was 87.2% vs 89.8% with electronic DOT. The percentage difference was −2.6% (95% CI, −4.8% to −0.3%). |

(*Continued*)


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**Table 1** (Continued).

| Study | Design | Country | Sample Size | Intervention | Comparison | Results |
|---|---|---|---|---|---|---|
| Guo et al (2019)[13] | RCT | China | 810 TB patients, IG (n=405); CG (n=405) | Video DOT (VDOT) | In-person DOT | • VDOT significantly saved time and was cost-effective; patients reported higher satisfaction with VDOT than DOT.<br>• Patients in the VDOT group had a better experience compared to those in the DOT group. They considered the method convenient and practical (p<0.001), would choose the original method if necessary (p<0.001), and would recommend the method to other patients (p<0.001). |
| Browne et al (2019)[14] | RCT | USA | 61 TB patients, IG (n=40); CG (n=21) | Wirelessly Observed Therapy (WOT) with ingestion sensor | DOT | • WOT showed 93% adherence, higher than DOT (63%) (*p*<0,001); preferred by patients, with high detection accuracy (99.3%).<br>• One hundred percent of participants preferred using WOT. |
| Gashu et al (2021)[31] | RCT | Ethiopia | 306 TB patients, IG (n=152); CG (n=154) | Phone-based weekly refilling and daily reminders | Routine care only | • Higher adherence (79% vs 66.4%) and improved provider-patient relationship (*p*=0,018); no significant effect on treatment success.<br>• TB treatment success was 89.5% (136/152) in the intervention group and 85.1% (131/154) in the control group. |
| Liu et al (2015)[17] | Cluster Randomized Trial | China | 4173 TB patients, 36 clusters | Electronic reminders with medication monitors | Standard case management without reminders | • The mean percentage of patient months with 20% or more missed medication doses was highest in the control group (29.9%), followed by the text messaging group (27.3%; aMR 0.94; 95% CI 0.71–1.24).<br>• This percentage decreased significantly in the medication monitoring group (17.0%; aMR 0.58; 95% CI 0.42–0.79) and the combined group (13.9%; aMR 0.49; 95% CI 0.27–0.88).<br>• Loss to follow-up was lower in the text messaging group than in the control group (aMR 0.42; 95% CI 0.18–0.98). |
| Johnston et al (2018)[32] | RCT | Canada | 358 LTBI patients, IG (n=170); CG (n=188) | Weekly two-way SMS reminders | Standard LTBI treatment without SMS | • Two-way SMS did not improve LTBI completion; high adherence in both arms.<br>• LTBI therapy in the intervention and control groups was 79.4% and 81.9%, respectively (RR 0.97, 95% CI 0.88–1.07; p=0.550). |
| Iribarren et al (2022)[33] | Pilot Randomized Controlled Trial | Argentina | 42 TB patients, IG (n=21); CG (n=21) | Mobile TB-TST app with drug metabolite test and support | Usual care without TB-TST intervention | • Feasible and acceptable; higher treatment success in the intervention group (95%) than control (81%).<br>• Participants (n=12) rated it as 'easy to use' (4.57/5) and 'highly recommend to others' (4.43/5). |
| Acosta et al (2022)[16] | RCT | Peru | 106 TB patients, IG (n=53); CG (n=53) | Medication event reminder monitor (MERM) | Standard DOT strategy | • Higher treatment success with MERM (RR 1.15); no difference in adherence outcomes.<br>• However, the intervention group had a lower percentage of patients who missed at least one dose and patients who missed more than 10% of total doses. |

(*Continued*)

**Table 1** (Continued).

| Study | Design | Country | Sample Size | Intervention | Comparison | Results |
|---|---|---|---|---|---|---|
| Liu et al (2023)[34] | Cluster Randomized Trial | China | 3.074 TB patients, 24 clusters | Medication monitor with daily reminders and monthly review | Silent-mode monitor-measured adherence only | • There was no significant difference in the risk of adverse outcomes (death, loss to follow-up, treatment failure, switching to drug-resistant TB treatment, or TB relapse) between the intervention and control groups (RR 1.01; 95% CI 0.73–1.40).<br>• Patients in the intervention group had a 57–64% reduction in missed drug doses.<br>• Relapse after 12 months of treatment was very low in both groups, at 1.9%. |
| Manyazewal et al (2022)[18] | RCT | Ethiopia | 114 TB patients, IG (n=57); CG (n=57) | Digital medication event reminder and monitor (MERM) | In-person DOT | • TB treatment adherence was comparable between intervention and control groups (p=0.954).<br>• Urine Isoniazid negative tests were more common in the control group (19.3%) than in the intervention group (3.5%) (p=0.008).<br>• There was no significant difference in clinical outcomes such as smear conversion and incidence of treatment side effects. |
| Story et al (2019)[35] | RCT | UK | 226 TB patients, IG (n=112); CG (n=114) | Smartphone-enabled Video Observed Therapy (VOT) | In-person DOT (3–5 times per week) | Higher observation adherence (70% vs 31%); improved patient satisfaction. |
| Fang et al (2017)[36] | RCT | China | 350 TB patients, IG (n=160); CG (n=190) | SMS-based reminders and core TB knowledge education | Standard DOT | • Improved treatment completion rate (96.25% vs 86.84%) and lower missed doses.<br>• After the treatment period, the re-examination rate of patients in the SMS group was significantly higher than that in the control group. |
| Farooqi et al (2017)[37] | RCT | Pakistan | 148 TB patients, IG (n=74); CG (n=74) | Daily SMS reminders on top of the usual DOTS | Standard DOT | • The SMS group had a lower default rate, but it was not statistically significant.<br>• Treatment failure was found in 7 (4.7%) patients, of which 3 patients (4.1%) were in "IG" and 4 patients (5.4%) were in "CG" (p = 0.983). |
| Kumwichar et al (2024)[38] | Cluster Randomized Controlled Trial | Thailand | 128 TB Patients IG (n=63; CG (n=65) | Video Observed Therapy (VOT) using the LINE application | Directly Observed Therapy (DOT) | • Patient and observer compliance was higher in the VOT group. The sputum conversion rate was higher in VOT (73%) than in DOT (61.5%), although the difference was not significant. |
| Tadesse et al (2024)[19] | Pragmatic Cluster Randomized Trial | Ethiopia | 3858 TB Patients 78 clusters | Smart pillbox with audio-visual reminders and medication labels | Standard of Care | • There was no significant reduction in unfavourable outcomes in either intervention, but medication labels showed a reduction in loss to follow-up (OR: 0.37, CI: 0.15–0.95). |

tuberculosis patients from various countries. Most of the studies came from China (n=5) and Ethiopia (n=3). Other countries, such as the USA, Thailand, and Pakistan, each contributed 2 studies. Meanwhile, countries such as Cameroon, Armenia, Moldova, Canada, Argentina, Peru, and the UK were each represented by 1 study. This shows that the studies have a diverse geographical coverage but focus more on specific countries, especially in Asia and Africa.

## Quality Appraisal and Risk of Bias of Included Studies

The JBI appraisal results showed that most RCT studies had suitable methodology with most criteria met with a JBI score >70% (See Table S2). All studies ensured the use of correct randomization and concealed group allocation. In addition, group similarity at the beginning of the study and treatment consistency across the two groups were also well maintained, thus minimizing bias. Overall, study scores ranged from 10 to 12 out of a total of 13 criteria assessed, reflecting good methodological quality, as seen in the study by Ravenscroft et al (2020), which obtained a score of 12/13,[29] and Story et al

(2019) which obtained a score of 11/13,[35] and other research. These high scores indicate that despite some weaknesses related to blinding, most studies had strong and consistent designs.

Most of the studies included in this risk of bias assessment demonstrated an overall high risk of bias, primarily due to issues in the randomization process (D1) and deviations from intended interventions (D2) (see Figures 2 and 3). While the majority of studies showed low risk in domains related to missing outcome data, outcome measurement, and selection of reported results (D3–D5), the weaknesses observed in the earlier domains significantly affected their overall judgement. Only three studies were rated as having a low overall risk of bias, while the rest were predominantly rated as high risk. A few studies, received a rating of "some concerns", indicating moderate methodological issues. Overall, these findings suggest that the methodological quality of most RCTs analyzed still requires improvement, particularly in ensuring proper randomization and consistent intervention implementation, which are critical for drawing reliable conclusions.

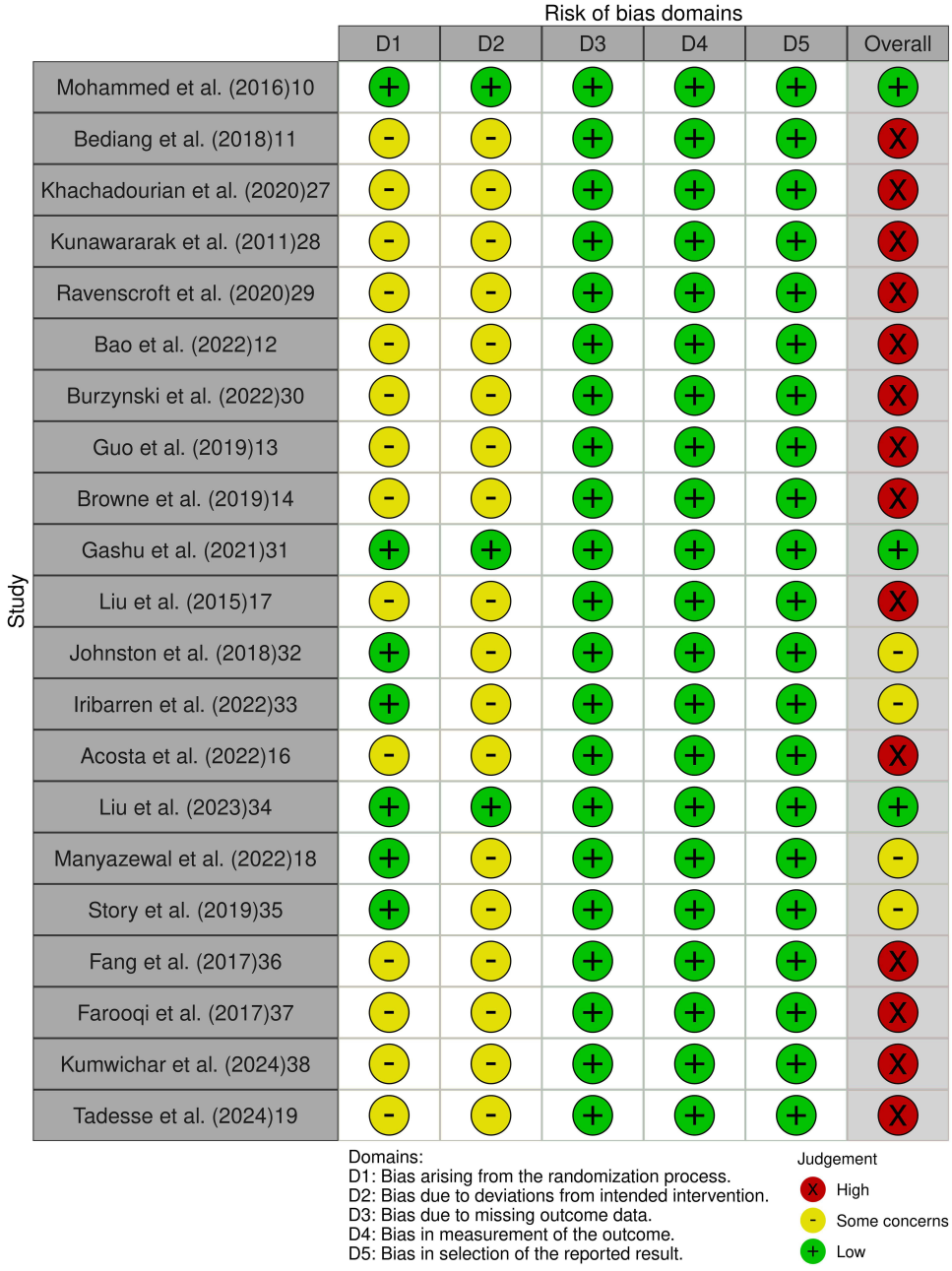


**Figure 2** RoB of Included Studies.

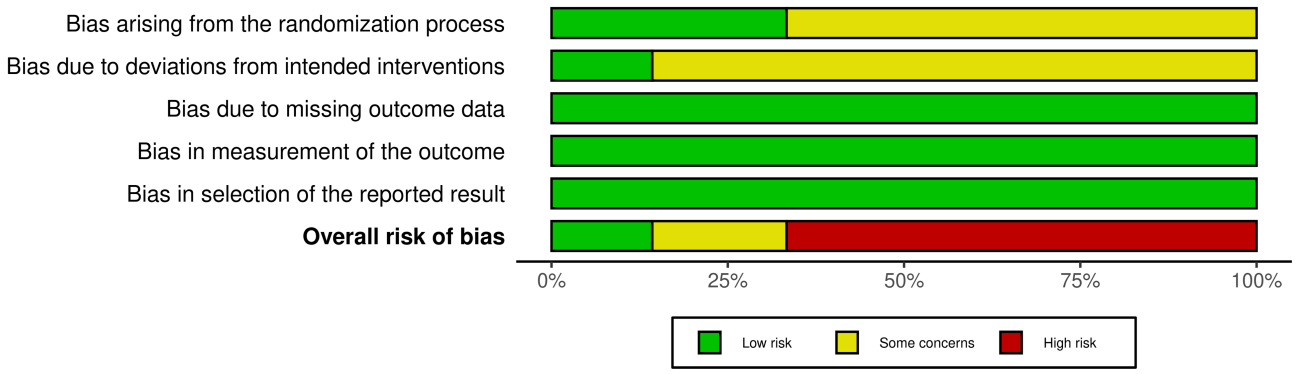


**Figure 3** Summary of RoB.

## Method of Digital Health Intervention

The 21 studies intervention methods, summarized in Table 2, involve a variety of digital technology-based approaches and other supports designed to improve tuberculosis treatment adherence and ensure continuity of care. These studies used a variety of digital technology-based approaches with varying implementation frequencies and content to support TB treatment adherence. In this review, intervention categories were classified based on the similarity of their intervention objectives or mechanisms.

**Table 2** Summary of Intervention Characteristics

| Study | Intervention | Media | Frequency | Content | Significant Outcome |
|---|---|---|---|---|---|
| Mohammed et al (2016)[10] | Daily SMS reminders (Zindagi SMS) | SMS | Daily SMS sent at a consistent time each day as reminders | Simple SMS reminder instructing patients to take their TB medication on time. | None. |
| Bediang et al (2018)[11] | Daily SMS reminders with usual treatment | SMS | Daily SMS reminders to take medication, scheduled consistently | SMS with medication reminders integrated with routine treatment instructions. | Treatment success. |
| Khachadourian et al (2020)[27] | Self-administered care with family support | Self-administration with family support | Continuous, self-monitored intake supported by family for daily adherence | Family-supported reminders and encouragement to maintain adherence; daily monitoring. | Treatment compliance rate. |
| Kunawararak et al (2011)[28] | Phone call reminder | Phone calls | Daily phone call reminders at set times to take medication | Phone calls used to reinforce daily medication schedule and address any adherence challenges. | Treatment completion rate. |
| Ravenscroft et al (2020)[29] | Video Observed Therapy (VOT) | Video (app) | Daily video observation; patients submit videos of medication intake every day | Video recording submission of each medication dose, enabling direct monitoring by health professionals. | Improve compliance, reduce costs for patients, and increase flexibility for patients. |

(*Continued*)


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**Table 2** (Continued).

| Study | Intervention | Media | Frequency | Content | Significant Outcome |
|---|---|---|---|---|---|
| Bao et al (2022)[12] | WeChat-based mHealth intervention | WeChat | Continuous availability of mHealth content; patients access educational and behavioural support as needed | Health education and behavioral reinforcement through messages on WeChat focused on self-management. | Improvements in knowledge about TB and involvement in their own care, medication adherence. |
| Burzynski et al (2022)[30] | Electronic DOT | Video conferencing | Daily video check-ins or as requested by healthcare provider | Live or recorded video sessions for adherence verification, ensuring observed therapy remotely. | Additional benefits in terms of convenience and time efficiency. |
| Guo et al (2019)[13] | Video DOT (VDOT) | Video | Daily video submissions for every medication dose are monitored by a central server | Remote observation through video; secure app allows patients to record each dose for staff review. | It is more cost effective and increases patient satisfaction. |
| Browne et al (2019)[14] | Wirelessly Observed Therapy (WOT) | Sensor-enabled device | Continuous ingestion sensor monitoring without specific reminders | Sensor-based ingestion tracking, which directly logs whether medication was taken. | Higher compliance is preferred by patients, and more accurate monitoring methods, with sensors verifying drug consumption. |
| Gashu et al (2021)[31] | Phone-based weekly refilling and daily reminders | Phone calls and SMS | Weekly refill reminder call, plus daily SMS medication reminders | Phone call reminders for weekly refills; daily SMS to reinforce medication schedule. | Higher compliance and better patient-provider relationships. |
| Liu et al (2015)[17] | Electronic reminders with medication monitors | Electronic monitor device and SMS | Continuous monitoring and reminders triggered by medication box opening | The medication box provides alerts when opened, with SMS reminders as backup. | Medication monitors and electronic reminders are effective in reducing the frequency of missed doses, helping patients maintain their medication schedule. |
| Johnston et al (2018)[32] | Two-way weekly SMS reminders | Two-way SMS | Weekly two-way SMS interaction to confirm adherence status | Two-way SMS allowing patients to confirm or ask questions about their adherence weekly. | High compliance in both groups. |
| Iribarren et al (2022)[33] | Mobile TB-TST app with drug metabolite test and support | Mobile app | Continuous tracking; app allows daily self-reports, symptom checks, and drug testing | The app records daily medication self-reports, symptom checks, and drug ingestion tests (via urine photos). | High acceptance rate and increased treatment success. |
| Acosta et al (2022)[16] | Medication event reminder monitor (MERM) | Electronic monitor device | Continuous, every box opening event triggers a reminder and logs adherence | Device reminders with logging of each adherence event for easy data access by healthcare providers. | Higher treatment success. |

(*Continued*)

**Table 2** (Continued).

| Study | Intervention | Media | Frequency | Content | Significant Outcome |
|---|---|---|---|---|---|
| Liu et al (2023)[34] | Medication monitor with daily reminders and monthly review | Electronic monitor device | Daily reminders via device and monthly review of adherence data by healthcare providers | The device logs medication events daily, provides monthly data reviews, and provides additional support for low adherence. | Reducing the dose of medication. |
| Manyazewal et al (2022)[18] | Digital medication event reminder and monitor (MERM) | Electronic monitor device | Daily reminders via device; tracks all events and records adherence continuously | Digital reminders through MERM device with regular adherence logs; real-time alerts for missed doses. | Adherence to treatment with MERM was non-inferior and superior in several parameters. |
| Story et al (2019)[35] | Smartphone-enabled Video Observed Therapy (VOT) | Smartphone app | Daily video submission for each dose, recorded and reviewed by health staff | Video submissions of each dose are securely reviewed by health staff to confirm adherence. | Higher compliance and satisfaction. |
| Fang et al (2017)[36] | SMS-based reminders and core TB knowledge education | SMS | Continuous SMS reminders with additional educational content on TB | SMS reminders reinforced by periodic messages with TB education for improved health literacy. | Treatment completion rates were higher and missed doses were lower in the SMS group. |
| Farooqi et al (2017)[37] | Daily SMS reminders on top of the usual DOTS | SMS | Daily SMS reminders, in addition to the usual DOTS protocol | SMS reminders to boost adherence to DOTS; consistent daily texts reminding of medication times. | The rate of medication irregularity was slightly lower in the SMS group, but the difference was not statistically significant. |
| Kumwichar et al (2024)[38] | Video Observed Therapy (VOT) using the LINE application | Smartphone (LINE app) | Daily reminders | Sending video of drug consumption to observers, daily notification via LINE. | Patient and observer compliance was higher with VOT than DOT. |
| Tadesse et al (2024)[19] | Smart pillbox with audio-visual reminders and medication labels | Audio-visual reminders and SMS | Daily (pillbox) or weekly (labels) | Audio-visual reminders from the pillbox and a weekly unique code to send the log via SMS. | Decreased loss to follow-up in the medication labels group. |


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## Reminders

Reminder-based interventions are used to help TB patients remember or carry out an action that needs to be done during the treatment process. Based on the results of the analysis, it was found that the reminder methods used by several studies varied considerably. Most studies used reminder methods such as SMS,[10,11,15,17,27,31,32,37] direct phone call or voice,[27,28,31] via LINE application,[38] and electronic pill box with audio/visual reminders.[16,17,19,34]

SMS reminder systems are generally carried out every morning (such as at 07:30–08:00) to remind people to take their medication or for brief education,[10,11,16,17,27,31,37] and weekly and monthly SMS are often used for medication refill reminders or clinic visits.[17,31,32] In Mohammed et al's (2016) study, SMS was sent 1–3 times a day, with a 2-hour interval if there was no response from the patient. Then, the study conducted phone calls every day to remind patients to take their medication, provide advice, and remind them of appointment schedules or sputum specimen collection,[27,28,31] and in the studies of Ravenscroft et al (2020) and Kumwichar et al (2024), telephone calls were made when patients forgot to send videos related to video observation therapy.[29,38] Observers can also provide input or corrections if the patient makes a mistake.[38]

The final method is an electronic pill box with audio/visual reminders.[17,19] Liu et al (2015) research, the reminder box provides beeping sounds and human voices to remind patients to take medication.[17] The MERM (Medication Event Reminder Monitor) electronic box sends audio/visual signals and SMS if the box is not opened at the scheduled time.[16] In Tadesse et al (2024), the smart drug brain is equipped with an audio-visual reminder that beeps or lights an indicator every morning at a specified time (6:00–11:00 a.m). When the patient opens the box to collect the medicine, the device automatically records the opening time and sends the data to a digital platform via mobile internet. If the box is not opened within the specified time, the system sends a notification to the patient and healthcare provider to follow up.[19]

## Remote Monitoring

Remote Monitoring is a method of monitoring patients remotely using technology. The goal is to collect health data in real time without requiring a direct visit to a health facility. The review results showed that the remote monitoring method uses technology such as MERM, mobile applications for self-reporting, digital sensors, and VDOT.[13,14,16,29,33] This technology enables remote medication adherence monitoring, automatic notifications, and real-time access to patients and healthcare workers.

Acosta et al (2022) offered a MERM intervention for continuity of care for TB patients.[16] In Acosta et al (2022), the MERM used was the Wisepill RT2000, an electronic pill box connected to a web server via a cellular network to monitor patient treatment in real-time. A signal is sent to the central management system (Wisepill Web Server) whenever the box is opened.[16] If the box is not opened at the scheduled time, the system sends up to 3 daily SMS to the patient, relatives and care monitor. These SMS remind them to take their medication or evaluate obstacles like connectivity issues or inappropriate doses. Patients are monitored until they complete 54 doses of the second phase of treatment (4 months) or more if treatment is extended.[16]

Iribarren et al (2022) used a mobile application called TB-TST to improve treatment adherence and facilitate remote support during therapy.[33] The TB-TST application is a tuberculosis treatment support tool that allows patients to report drug consumption independently, report side effects, and send photos of urine test results to monitor treatment compliance.[33] The app also provides interactive features, such as communication with treatment supporters, access to accurate information about TB, a treatment calendar to track progress, and a group discussion forum with other patients. In this study, patients were asked to report their daily treatment management and complete urine tests three times a week on weekdays.[33]

Another method is Wireless Observed Therapy (WOT).[14] The WOT method is an innovative system that allows digital monitoring of drug consumption through a combination of an ingestible sensor (IS), an external patch worn on the skin, and a connected mobile device. The sensor, made of minerals and swallowed with TB drugs, sends signals to the mobile device to record the time of drug consumption and is stored on a cloud-based platform.[14] Patients and health workers can access drug consumption data in real-time. This system informs health workers if the drug is not consumed according to schedule.[14]

Guo et al (2019) used video-directly observed therapy (VDOT) to monitor treatment in TB patients. VDOT was conducted using an information platform equipped with a smartphone application.[13] Before starting, health workers train patients to use the application and go through the VDOT process. After being included in the study, patients will receive a medication reminder schedule via notification to their phone using a unique public number.[13] At the scheduled time, the patient connects with the administrator via live video to take medication under supervision. The patient can also complain about the disease or treatment in this video session. If the patient misses the VDOT schedule, follow-up is done through phone calls and, if necessary, home visits.

## Outcome of Intervention

Based on the analysis results, it was found that digital interventions have benefits in improving the outcomes of TB patients. Six studies reported that digital-based interventions can improve compliance,[14,18,29,32,34,35] reduce the missed dose of medication,[17,34] and the success and completion of treatment.[16,27,31,33,36] In addition, TB patients also reported better efficiency and costs,[13] improving patient relationships with service providers,[31] better experience, found the method convenient, practical, and were willing to recommend it to other patients.[13,14,33] These results underscore the important role of technology in supporting continuity of care. Interventions such as VDOT, VOT, MERM and others ensure continuous treatment monitoring, even without the physical presence of the patient and health care provider.

However, not all studies reported positive outcomes. For example, Mohammed et al found no significant improvement in treatment success or adherence among TB patients.[10] Bediang et al also reported no significant impact on adherence.[11] Kunawararak et al found no meaningful change in sputum conversion rates,[28] and Johnson et al observed low completion rates in latent TB infection (LTBI) treatment.[32] Furthermore, Liu et al reported continued issues with patient death and loss to follow-up, despite the use of digital interventions.[34]

# Discussion

This systematic review explores the effectiveness of technology-based interventions in TB patients and their benefits in continuity of care. The findings of this review show two types of digital technology-based methods designed to improve tuberculosis treatment adherence, namely reminders and remote monitoring. These methods are diverse and innovative interventions to improve continuity of care and treatment adherence in TB patients.

Several studies used methods with various digital tools such as SMS, phone calls, MERM, and mobile applications. Each intervention was tailored to the specific needs of TB patients, focusing on medication reminders, clinic visit schedules, and medication adherence reporting. SMS reminders were among the most frequently used methods,[10,11,15,17,27,31,32,37] with daily delivery to improve medication adherence or weekly/monthly to remind clinic visits and refills.[10,11,16,17,27,31,37] SMS media is the most widely used method due to its low cost, broad accessibility, and ability to reach patients in areas with limited technological infrastructure.[36,37] Telephone calls, although more expensive, are a direct means of communication that helps strengthen the relationship between patients and healthcare providers, with compliance rates of up to 79% compared to the control group.[31] The effectiveness of this reminder method shows the potential for simple but strategic interventions in overcoming the challenges of TB patient medication adherence. This method can help reduce the risk of treatment failure due to patient forgetfulness or negligence, thereby increasing the chances of successful therapy and preventing drug resistance.[17,31,32]

The remote monitoring methods used in several studies are diverse. Remote monitoring technologies such as MERM, mobile applications, and VDOT further strengthen the continuity of care by allowing real-time health data collection and remote patient monitoring. These tools reduce the need for frequent clinic visits and empower patients and healthcare workers with direct access to adherence data and automated notifications.[13–16,29,33] VDOT and MERM systems allow healthcare workers to monitor patient behaviour remotely, reducing the need for direct supervision in the field. Integrating these technologies into TB care promotes a more responsive, patient-centered approach, ultimately improving treatment outcomes and reducing the risk of disease transmission.[13,16,18] The main benefits of this approach are time and resource efficiency for both patients and the health system, providing more consistent oversight and encouraging active patient engagement in their care. Integrating this technology into TB care promotes a more responsive and patient-centred approach, ultimately improving treatment outcomes and reducing the risk of disease transmission.[16,18,29]

Using digital interventions in TB management has brought significant benefits, particularly in improving treatment adherence.[14,18,29,32,34,35] This is confirmed by previous reviews that reported the same thing.[39,40] Another advantage of digital interventions is time and cost efficiency. Previous studies have shown that using VOT and Video DOT (VDOT) significantly saves time and is more cost-effective than face-to-face DOT.[13] Patients reported higher satisfaction levels with this digital method because it was perceived as practical, convenient, and accessible anytime.[13,14,33] Most patients stated that they would recommend this method to others. In addition, reducing travel costs and time spent in health facilities provides economic benefits, especially for patients from low socio-economic groups.[41]

While DHIs have demonstrated potential, their overall effectiveness is not consistent across studies, reflecting the influence of contextual, behavioral, and systemic factors. Mohammed et al found no significant improvements in adherence or treatment success,[10] while Bediang et al similarly reported no difference in adherence between intervention and control groups suggesting that technological solutions alone may be insufficient to address underlying motivational or structural barriers.[11] In addition, previous study showed that no impact on sputum conversion, indicating that certain DHIs may not influence biological outcomes when broader determinants of health remain unaddressed.[28] In the context of latent TB infection, Johnson et al highlighted persistently low treatment completion rates despite the use of DHIs, emphasizing challenges in asymptomatic populations where perceived treatment urgency is low.[32] Furthermore, Liu et al reported continued mortality and loss to follow-up, illustrating the limitations of DHIs in overcoming social vulnerability, health system weaknesses, and patient disengagement.[34] Collectively, these findings underscore that while DHIs offer valuable tools, their success depends on being embedded within supportive, patient-centered, and context-sensitive care models.

The review results showed that SMS was the most widely used method due to its simplicity. At the same time, VOT was the most influential method due to its high flexibility, cost-effectiveness, and superior compliance rate. However, for ease of use, SMS and mobile applications are the best solutions in digital-based interventions, considering the availability of technology.[36,37] The results of this study indicate that by combining several methods, such as SMS and VOT, the level of adherence and results of TB treatment can be significantly improved and have a broader impact on managing this disease. Through this digital-based intervention, patients can ask about drug side effects, treatment schedules, and possible complaints and receive social support that can improve their adherence to treatment to improve the quality of life of TB patients.[12,42,43]

Despite the many benefits of applying technology in TB management, applying digital interventions presents several challenges and limitations, especially in environments with limited resources.[40,44,45] One of the main challenges is the gap in access to technology, especially in areas with limited communication infrastructure, such as rural or remote areas that often do not have access to devices such as mobile phones or stable internet connections.[13,31,46] The adaptability of digital devices to local environments is often limited by software and hardware requirements. Technology failures can lead to a loss of trust among users, reducing the effectiveness of interventions.[44] Issues such as poor mobile phone coverage, digital adherence technologies (DAT) failures, and technical issues with the platform are common.[45] In addition, low literacy levels are a barrier, especially for methods such as SMS, which require patients to be able to read and understand text messages.[36,37,46]

In addition, the success of this intervention also depends on the acceptance of patients and health workers. Some patients may feel uncomfortable with digital surveillance due to privacy, stigma, or cultural reasons. In some communities, traditional health practices may be deeply rooted, leading to resistance to adopting new technologies. Overcoming these cultural barriers through community engagement and education is critical to successful implementation.[41,47] Lack of understanding or trust in new technologies among health workers can also hinder the implementation of digital-based methods.[17,33] Addressing these challenges requires careful planning, investment in local resources, and the development of robust feedback and communication systems. By addressing these barriers, digital health technologies can improve TB treatment adherence and outcomes, especially in resource-constrained settings.

## Implication for Practice

Digital technologies in TB management, such as VDOT, MERM, and SMS-based reminders, can facilitate continuity of care for TB patients. Health workers can use these technologies to monitor patients in real-time, reduce the need for in-

person visits, and improve the efficiency of care, especially in areas with limited access. This integration of technologies helps maintain continuity of treatment while supporting more optimal resource allocation.

Training for health workers and infrastructure support, such as internet access and electronic devices, are needed for its success. Governments and policymakers also need to encourage the development of technologies that are appropriate to local needs. When appropriately implemented, digital technologies can be a critical innovation in improving patient outcomes and strengthening health systems.

### Strengths and Limitations of Study

This review provides a structured synthesis of various DHIs used to support TB treatment, categorized based on intervention mechanisms such as reminders and remote monitoring. By highlighting the potential of these technologies to improve patient adherence, optimize healthcare worker performance, and ensure treatment continuity, the review offers practical insights for strengthening TB programs, particularly in resource-limited settings. Furthermore, the inclusion of recent studies and adherence to PRISMA guidelines enhance the methodological rigor and relevance of the findings to current digital health landscapes.

Despite its contributions, this review has several limitations. The number of included studies and participants remains limited, which may restrict the generalizability of the findings. In addition, there is a regional overrepresentation of studies from specific countries, particularly China and Ethiopia, potentially skewing conclusions if not interpreted within the appropriate local context. The diversity of social, cultural, and infrastructural conditions across countries is not fully reflected, which may affect the applicability of certain interventions globally.

## Conclusion

Reminder-based and remote monitoring digital interventions offer substantial benefits in supporting continuity of care for TB patients. Reminder tools including SMS, phone calls, and electronic pillboxes are effective in improving patient adherence to medication schedules and clinical appointments. Meanwhile, remote monitoring technologies such as VDOT, MERM, and mobile applications facilitate real-time observation and support, even in the absence of face-to-face interaction between patients and healthcare workers. These interventions not only improve medication adherence, treatment success rates, and patient-provider communication but also offer time and cost efficiencies. Many patients perceive these tools as convenient, empowering, and conducive to a more positive treatment experience.

To maximize public health impact, DHIs should be systematically integrated into national TB control programs, in alignment with global strategies such as the WHO End TB Strategy, which emphasizes person-centered care, digital innovation, and equitable access. Effective implementation requires careful consideration of potential challenges, including limited internet infrastructure, low levels of digital literacy, and resistance to technology adoption particularly in rural and underserved areas. Addressing these challenges calls for adaptive approaches, such as community-based digital education, culturally appropriate intervention designs, and phased implementation tailored to local capacity and context. In addition, comprehensive training and ongoing support for healthcare workers play a vital role in ensuring successful adoption and operational sustainability. Further research is needed to evaluate long-term effectiveness, cost-efficiency, and the equity implications of digital interventions, especially within low-resource settings. When implemented thoughtfully, DHIs offer a scalable and adaptable solution to accelerate progress toward global tuberculosis elimination goals.

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The authors declare no conflicts of interest in this work.

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