Effectiveness of electronic reminder systems in improving treatment adherence and completion rates in tuberculosis patients: a meta-analysis

Eficacia de los sistemas de recordatorios electrónicos para mejorar el cumplimiento del tratamiento y las tasas de finalización en pacientes con tuberculosis: un metaanálisis

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Abstract

Introduction: Numerous studies have evaluated electronic reminder systems (ERSs) to enhance tuberculosis (TB) treatment outcomes, but recent findings are inconsistent.
Objective: This study aimed to evaluate the effectiveness of ERSs in improving treatment adherence and completion among TB patients.
Methodology: A systematic review and meta-analysis design. The included studies were obtained from six databases (PubMed, MedLine Ultimate, WOS, ASC, CINAHL, and Garuda) up to May 26, 2025. Risk of Bias tool was employed to assess the article quality. The odd ratio (OR) was calculated and analysed using random-effect and 95% confidence interval (CI).
Results: Eleven studies were eligible criteria in this review. ERS significantly improved treatment adherence (OR = 1.97, 95% CI [1.05, 3.69], p = 0.04; I^2 = 85%) and treatment completion (OR = 1.57, 95% CI [1.08, 2.27], p = 0.02; I^2 = 75%). Subgroup analysis showed a significant effect on adherence in low- and middle-income countries (LMICs) (OR = 1.97, 95% CI [1.16, 3.35], p = 0.01; I^2 = 0%), but not in upper-middle-income countries (UMICs) (OR = 1.87, p = 0.14; I^2 = 91%). No subgroup reached statistical significance for completion, though the overall effect remained robust. The test for subgroup differences was non-significant for both outcomes (p = 0.92 for adherence; p = 0.11 for completion).
Conclusions: ERS are effective in improving TB treatment adherence and completion, with the strongest and most consistent evidence in LMICs. These findings support their integration into national TB programs in resource-limited settings as a low-cost, scalable adjunct to standard care. These findings reinforce that simple digital tools can make a meaningful difference, especially when thoughtfully deployed in the wide settings.
Registration: CRD420251072331 was registered in PROSPERO.

Keywords

Tuberculosis; electronic reminder; adherence; completion.

Resumen

Introducción: Numerosos estudios han evaluado los sistemas de recordatorios electrónicos (ERS) para mejorar los resultados del tratamiento de la tuberculosis (TB), pero los hallazgos recientes son inconsistentes.
Objetivo: El objetivo de este estudio fue evaluar la eficacia de los ERS para mejorar el cumplimiento y la finalización del tratamiento entre los pacientes con TB.
Metodología: Diseño de revisión sistemática y metaanálisis. Los estudios incluidos se obtuvieron de seis bases de datos (PubMed, MedLine Ultimate, WOS, ASC, CINAHL y Garuda) hasta el 26 de mayo de 2025. Se utilizó la herramienta Risk of Bias para evaluar la calidad de los artículos. Se calculó y analizó la odds ratio (OR) utilizando el efecto aleatorio y el intervalo de confianza (IC) del 95 %.
Resultados: Once estudios cumplieron los criterios de elegibilidad para esta revisión.
El ERS mejoró significativamente la adherencia al tratamiento (OR = 1,97, IC del 95 % [1,05, 3,69], p = 0,04; I^2 = 85 %) y la finalización del tratamiento (OR = 1,57, IC del 95 % [1,08, 2,27], p = 0,02; I^2 = 75 %). El análisis de subgrupos mostró un efecto significativo sobre la adherencia en los países de ingresos bajos y medios (PIBM) (OR = 1,97, IC del 95 % [1,16, 3,35], p = 0,01; I^2 = 0 %), pero no en los países de ingresos medios-altos (PIMA) (OR = 1,87, p = 0,14; I^2 = 91 %). Ningún subgrupo alcanzó significación estadística en cuanto a la finalización, aunque el efecto global siguió siendo sólido. La prueba de diferencias entre subgrupos no fue significativa para ninguno de los dos resultados (p = 0,92 para la adherencia; p = 0,11 para la finalización).
Conclusiones: Los ERS son eficaces para mejorar el cumplimiento y la finalización del tratamiento de la tuberculosis, con la evidencia más sólida y consistente en los países de ingresos bajos y medios. Estos hallazgos respaldan su integración en los programas nacionales contra la tuberculosis en entornos con recursos limitados como un complemento de bajo costo y escalable a la atención estándar. Estos hallazgos refuerzan la idea de que las herramientas digitales sencillas pueden marcar una diferencia significativa, especialmente cuando se implementan de forma cuidadosa en los entornos adecuados.
Registro: CRD420251072331 se registró en PROSPERO.

Palabras clave

Tuberculosis; recordatorio electrónico; adherencia; finalización.

Introduction

Tuberculosis (TB) continues to rank among the foremost causes of mortality from infectious diseases globally, despite notable progress in medical science and public health intervention (Suvvari, 2025). According to the World Health Organization (WHO), TB has re-emerged as the leading cause of death from infectious diseases in 2023, overtaking COVID-19. With approximately 8.2 million newly diagnosed cases, the imperative to address this enduring global health threat has intensified (Wei & Zhang, 2024). Despite being a preventable and treatable disease, the success of TB control programs is critically undermined by poor patient adherence and incomplete treatment (Gygli et al., 2017), which contribute to prolonged infectiousness, increased transmission, and the emergence of multidrug-resistant TB (MDR-TB) strains (Hirpa et al., 2013).

The successful management of TB requires patients to adhere strictly to complex, long-term treatment regimens that typically span 6-9 months, often administered under the Directly Observed Therapy (DOT) strategy (WHO, 2025). Conventional DOT faced substantial implementation challenges (Adejumo et al., 2017). Although TB medications are provided at no cost, adherence imposes persistent non-financial burdens on patients and their families (Rabinovich et al., 2020). These include adverse drug reactions, loss of income, transportation costs, social stigma, and potential infringements on personal autonomy (Abdulkader et al., 2019). A persistent obstacle is the reliance on face-to-face supervision and support, which is particularly challenging in resource-limited settings where patients are often geographically dispersed and difficult to reach.

In response to these challenges, ERSs including short message service reminders, mobile health applications, electronic pillboxes, and video-observed therapy (VOT) have emerged as promising tools to enhance adherence and treatment completion. These interventions leverage digital technologies to provide timely reminders, monitor medication intake, and facilitate remote supervision, thereby reducing the need for in-person visits and improving patient autonomy (Bediang et al., 2018; Guo et al., 2020; Ravenscroft et al., 2020). Additionally, the End TB Strategy advocates for intensified research and innovation to accelerate the development and adoption of novel tools and interventions that enhance TB program efficiency (Dartois & Rubin, 2022). Among these, digital health technologies are being explored for their potential to support patient engagement and improve adherence and treatment completion across diverse settings (Huda et al., 2024).

Recent studies have demonstrated the effectiveness of these interventions. For instance, the use of Medication Event Reminder Monitor (MERM) systems has been associated with significantly higher adherence and completion rates (Acosta et al., 2022; Manyazewal et al., 2022). Similarly, it has shown comparable or superior outcomes to traditional DOT, with increased patient satisfaction and reduced costs (Burzynski et al., 2022; Story et al., 2020). Meta-analysis evidence suggests that technology-based interventions can improve treatment adherence and completion (Huda et al., 2024).

Moreover, A recent review found that various technology-based interventions significantly improved TB treatment outcome and its findings underscore the potential of technology assists to enhance TB treatment outcomes, especially in settings where traditional approaches are infeasible (Huda et al., 2024). Moreover, most studies have been conducted in high-income countries, leaving a critical gap in understanding the applicability and effectiveness of ERSs in low- and middle-income settings where TB burden is highest (Octaviani et al., 2024; Olowoyo et al., 2025). While individual studies and reviews have explored the impact of digital interventions on TB treatment adherence, there is a lack of comprehensive synthesis focusing specifically on ERS and their role in enhancing both adherence and treatment completion.

However, despite these promising findings, the literature remains fragmented, with considerable the heterogeneity in intervention types, study designs, and outcome measures across existing literature highlights a critical research gap. A systematic and rigorous evaluation of whether ERS interventions may determine their true effectiveness and inform policy and practice is needed. This meta-analysis aims to fill that gap by synthesizing current evidence on the impact of ERS interventions on TB treatment adherence and completion, thereby contributing to the optimization of TB care strategies worldwide.

Method

This systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines, which provide an evidence-based framework for transparent and comprehensive reporting (Page et al., 2021). A detailed protocol was developed and prospectively registered with PROSPERO, the international database for systematic reviews in health and social care (Registration ID: CRD420251072331).

Search strategy

Two authors performed comprehensive searches in relevant studies from the inception of six databases to 26 May 2025 including: PubMed, MedLine Ultimate, Web of Science, ASC, CINAHL, and Garuda without date restriction. The Medical Subject Headings and keywords for the search algorithm is displayed in Table 1.

Table 1. Search Strategies

Group	Search Terms
#1	adherence OR attachment OR faithfulness OR loyalty OR obedience OR obey OR comply
#2	e-promotion OR e-information OR web OR mobile education OR virtual education OR electronic education OR electronic promotion OR electronic learning OR digital education OR digital information OR digital promotion OR m-health OR tele-health OR telehealth OR tele OR e-health OR mobile OR internet OR mobile app OR application OR reminder OR sms OR phone OR message OR mobile OR notice OR call
#3	tuberculosis OR tbc1
#4	rct OR randomized control trial OR randomized control study OR trial
#5	#1 AND #2 AND #3 AND #4

Eligibility criteria

The inclusion criteria followed the PICOs principles (P: Participants; E: Exposures; C: Comparisons; O: Outcomes; S: study design), as shown below:

1) P : diagnosed with tuberculosis (pulmonary or extrapulmonary);
2) I : Use of ERS (i.e., short message service (SMS); Mobile application; Automated phone calls or other digital communication tools);
3) C : Comparator: Usual care, no intervention, or alternative non-electronic intervention;
4) O: TB treatment: (1) Adherence: Defined as the proportion of doses taken at least 80% of the total prescribed dose; and (2) Completion: Defined as the completion of the full dose of prescribed TB treatment;
5) S : Prospective or retrospective randomized controlled trials design;

For the studies were excluded if:

1) Indirect delivery of the intervention without involved patients
2) Not accessible in full text.
3) Not report quantitative data on adherence or completion rates.
4) Not published in English and Indonesia.

Study Selection

All identified publication references were imported into Endnote X9 software (Clarivate Inc.). The initial selection phase involved duplicate removal followed by title and abstract screening. Full-text articles of potentially relevant studies were then retrieved and evaluated against the inclusion and exclusion criteria. Dual independent screening of abstracts and full texts was performed by two authors, with disagreements resolved through consensus discussion with a third team member. Figure 1 presents PRISMA flowchart documenting the study selection process (Page et al., 2021).

Two independent authors (NMA and YDLS) carried out the study selection process. Titles and abstracts were first screened to identify potentially relevant studies according to the inclusion and exclusion criteria. Full-text versions of the selected articles were then obtained and assessed in detail. Studies were ultimately included based on the eligibility criteria established above. Discrepancies between authors were addressed and resolved through mutual consensus with other authors.

Data Extraction

Data extraction was performed using a structured collection form designed according to the Template for Intervention Description and Replication (TIDieR) Checklist and Guide (Hoffmann et al., 2014). The following information was systematically extracted from each included study: author name; year of publication; country; study design; participant demographics (age and characteristics); study setting; intervention components; threshold, follow up; intervention protocol (i.e., modality, frequency, duration, strategy, reinforcement, content), and primary findings (adherence and completion rate).

Risk of Bias

The Cochrane Risk of Bias Tool 2 (RoB2) was used to critically appraise the quality of the included randomized controlled trials (Higgins et al., 2011). This assessed the methodological quality of studies in terms of randomization and concealment of subject allocation, blinding of subjects and outcome assessors, proportion of missing data, selective reporting and other sources of bias. The risk of bias for each domain was categorized into the following three levels: low, high and unclear. The critical appraisal process was completed independently by the two reviewers. Any disagreements were resolved, and a consensus was reached through discussions and consultations with all researcher members.

Quality assessment

The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach was used to assess the overall strength of evidence for the outcomes (Guyatt et al., 2011). This methodology considers five domains: risk of bias, imprecision, inconsistency, indirectness, and publication bias that assigns a certainty rating to each outcome as 'very low', 'low', 'moderate', or 'high'.

Statistical analysis

This meta-analysis included both individually RCT and cluster-RCT. For individually randomized studies, original event counts and sample sizes were used without adjustment, assuming independence between participants. For cluster-RCT studies, we applied the Effective Sample Size (ESS) method to correct for clustering effects, following the Cochrane Handbook (version 6.4, Chapter 23) (Higgins & Eldridge, 2023). The design effect (DE) was calculated as:

$$DE = 1 + (M - 1) \times ICC$$

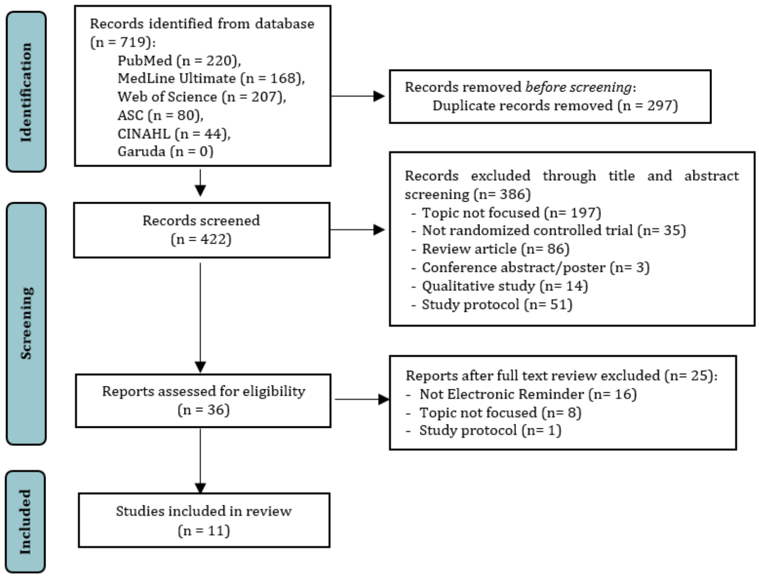
where M is the average cluster size and ICC is the intraclass correlation coefficient. In the absence of reported ICCs, the parameter classically used to quantify the clustering effect was performed using ICC= 0.05 to assess the robustness of results (Martin et al., 2018), based on prior literature in intervention effect estimates in cluster randomized versus individually randomized trials (Leyrat et al., 2019). Adjusted event counts and sample sizes were rounded to the nearest integer for compatibility with using Review Manager Software (v.5.4.1, Cochrane Collaboration Inc.). The analysis of intervention outcomes was conducted using forest plots were employed to synthesize the findings from the included studies. Odds ratios (ORs) were utilized to assess the effects of ERS on TB treatment adherence and completion. A 95% confidence interval (CI) was applied to quantify the deviation from the point estimate for each individual study as well as from the overall pooled estimate. Statistical heterogeneity among the included studies was evaluated using the I^2 statistic and p-value (Deeks et al., 2022). A fixed-effects model was used when $I^2 \leq 50\%$; otherwise, a random-effects model was applied. Statistical significance was determined at $p < 0.05$ (Deeks et al., 2022).

Results

Study Selection

An initial total of 719 articles was identified through searches across six electronic databases. After 297 duplicates were removed both automatically and manually, 386 articles were excluded during the title and abstract screening. The full texts of the remaining 36 articles were then reviewed, leading to the inclusion of 11 studies in the systematic review. The search and selection process are presented in Figure 1.

Figure 1. Prisma flowchart – Study selection process



Included Studies Characteristics

Based on table 2, there are eleven studies conducted across geographical regions, including South America, Africa, Asia, and North America. The studies targeted populations with drug-sensitive pulmonary tuberculosis (DS-PTB) or latent TB infection (LTBI), with sample sizes ranging from 106 (Acosta et al., 2022) to 4173 (Liu et al., 2015). Participants were recruited from various healthcare settings, such as primary care clinics, TB diagnostic centres, and urban health facilities. Age distributions varied, with median ages spanning from 26.3 years (Acosta et al., 2022) to 57 years (Wei et al., 2024), few studies did not report age explicitly.

TB Treatment durations and measurement time points differed across studies. Most interventions were evaluated over the standard 6-month TB regimen, while some focused on specific phases, such as the 2-month intensive phase (Manyazewal et al., 2022) or the 4-month continuation phase (Gashu et al., 2021). Adherence was typically assessed through self-report, pill counts, electronic monitoring, or biochemical verification (e.g., urine INH tests), with thresholds ranging from ≥80% to ≥90% of prescribed doses. Completion was defined variably, including full regimen completion, sputum conversion (cure), or WHO-defined treatment success (Fang et al., 2017; Gashu et al., 2021; Louwagie et al., 2022; Mohammed et al., 2016).

Across the studies, adherence and completion outcomes varied. Significant improvements in treatment completion were observed in intervention groups achieving completion rates more than 94% compared to lower rates in control groups (Acosta et al., 2022; Fang et al., 2017; Wei et al., 2024). An included study reported a substantial increase in adherence (Charalambous et al., 2024), while two studies also demonstrated statistically significant gains in adherence favouring the intervention arms (Gashu et al., 2021; Manyazewal et al., 2022). In contrast, three studies reported no significant differences in adherence or completion between groups, suggesting potential ceiling effects or limitations in intervention impact (Johnston et al., 2018; Liu et al., 2015; Mohammed et al., 2016).

Table 2. Included study characteristics

Study/Country	Design	Population	Age Mean/Median	Setting/ Study subject	Measurement Time	Main Findings
Acosta (2025)/ Peru	RCT	106 DS-PTB patients completing Phase 1 treatment	Median: 26.32	19 Ministry of Health primary centres I: n= 49 C: n= 53	4 months treatment + 1- month eval	Adherence I: n= 38/49 (77.6%) C: n= 33/53 (71.7%) p= 0.498 Completion I: n= 48/49 (98%) C: n= 45/53 (84.9%) p= 0.03
Bediang (2018)/ Cameroon	RCT	279 adults with smear-positive pulmonary TB (SS+ PTB)	Not explicitly reported	12 TB Diagnostic & Treatment Centres I: n= 137 C: n= 142	6 months total (2 months intensive phase + 4 months continuation)	Completion I: n= 111/137 (81%) C: n= 106/142 (74.6%) p= 0.203
Charalambous (2024)/ South Africa	Cluster-RCT	2657 DS-TB patients across 18 clinics	Median: 36 (IQR 27–45)	Primary care clinics in 3 provinces I: n= 1306 C: n= 1278	6-month treatment + 12 months follow-up	Adherence I: n= 1056/1306 (80.86%) C: n= 650/1278 (50.86%) p<0.001
Fang (2017)/ China	Cluster-RCT	350 pulmonary TB patients	Mean: I: 47.59 C: 50.39	TB clinics in six counties/districts I: n= 160 C: n= 190	6-month treatment period	Completion I: n= 154/160 (96.25%) C: n= 165/190 (86.84%) p= 0.002
Gashu (2021)/ Ethiopia	RCT	306 adults with drug-sensitive TB on continuation phase	Not explicitly reported	22 facilities (health centres + hospitals) I: n= 152 C: n= 154	4-month continuation phase	Adherence I: n= 110/139 (79.1%) C: n= 95/143 (66.4%) p= 0.018 Completion I= 136/152 (89.5%) C= 131/154 (85.1%) p= 0.123
Johnston (2018)/ Canada	RCT	358 adults initiating LTBI therapy	Median: I= 45 (IQR 34-55) C= 42 (IQR 33-50)	2 specialized TB clinics I: n= 170 C: n= 188	6 months (RIF) or 12 months (INH)	Completion I: 135/170 (79.4%) C: 154/188 (81.9%) p= 0.550
Liu (2015)/ China	Cluster-RCT	4173 new PTB patients across 36 districts/counties	Median: 43	County/district TB clinics I: n= 1108 C: n= 1004	Full 2-month intensive phase + 4-month continuation	Adherence I= 451/996 (45.3%) C= 465/1,091 (42.6%) Completion I= 913/966 (45.3%) C= 946/1,066 (42.6%)
Louwagie (2019)/ South Africa	RCT	574 adults with DS-PTB + smokers and/or harmful drinkers	Mean: I= 38.56 C= 39.37	27 primary clinics in 3 districts I: n= 283 C: n= 291	6–9 months outcome + 3 and 6-month intermediate measures	Adherence I: n= 59/65 (90.8%) C: n= 61/68 (89.7%) Completion I: n= 192/283 (67.8%) C: n= 204/291 (70.1%)
Manyazewal (2022)/ Ethiopia	RCT	114 adults with bacteriologically confirmed DS-PTB	Mean: 32.9	10 urban healthcare facilities I: n=57 C: n=57	Full 2-month intensive phase	Adherence I= 57/57 (100%) C= 55/57 (96.5%)
Mohammed (2016)/ Pakistan	RCT	2207 Pulmonary TB patients (newly diagnosed)	Mean: 33	Public/private clinics and labs: I: n=1,110 C: n=1,097	6–8 months treatment phase	Completion I: n=917/1,104 (83.06%) C: n=903/1,093 (82.16%) p = 0.782
Wei (2024)/ Tibet	RCT	276 new PTB patients across 6	Median: I = 57 (IQR 40.2-	County-level TB dispensaries	6–7 months treatment (monthly adherence	Completion: I = 133/142 (94%)

	counties	64.8) C = 55 (IQR 40.2-64.8)	I: n= 142 C: n= 134	assessment)	C = 98/134 (73%) p < 0.001

Note: TB= RCT= Randomized Control Trial; Tuberculosis; DS-PTB =drug-sensitive pulmonary tuberculosis; LTBI= latent TB infection; IQR= Interquartile Range; WHO= World Health Organization; ARMS= Adherence to Refill and Medication Scale; INH= Isoniazid; RIF= Rifampisin; PTB= pulmonary TB; TB (SS+ PTB) = sputum-smear-positive pulmonary TB.

Interventions Characteristics

The intervention protocols across the reviewed studies demonstrated varied approaches to digital adherence support, structured around six core elements. Most studies employed SMS as the primary reminder modality, either alone or integrated with digital pillboxes or mobile apps. Reminder frequency was predominantly daily, though some protocols used weekly or biweekly schedules. The duration of reminders ranged from short-term (2 months) to full treatment courses and extended follow-ups up to 12 months. Reminder strategies included passive alerts, motivational messaging, differentiated care, and real-time feedback, often tailored to patient needs. Reinforcement mechanisms varied, with some studies incorporating provider reviews, phone call follow-ups, or escalation to video-observed therapy, while others lacked reinforcement entirely. The contents of reminders ranged from neutral dose-time prompts to culturally adapted graphics, motivational phrases, wellness check-ins, and educational messages, reflecting a balance between functional and psychosocial support (Table 3).

Table 3. Intervention Protocol

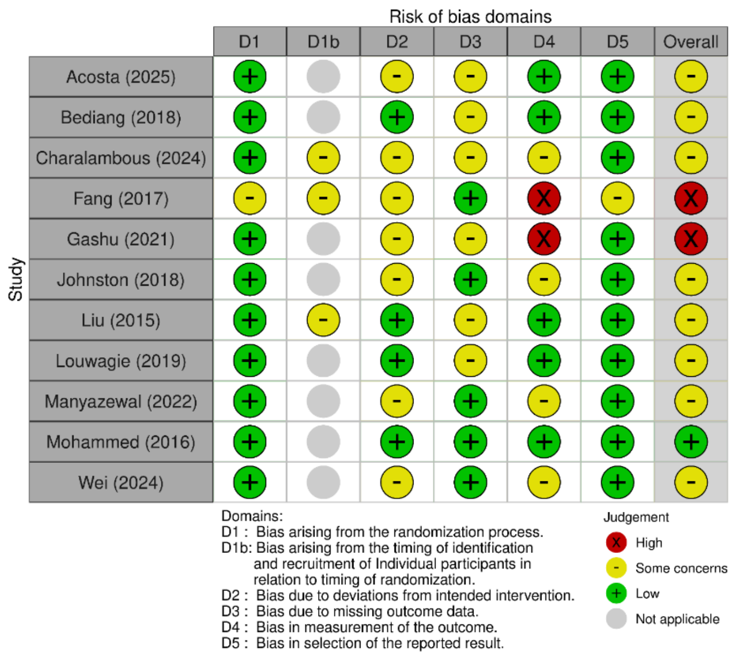
Study	Modality	Frequency	Duration	Strategy	Reinforcement	Contents of Reminders
Acosta (2025)	MERM (pillbox) + SMS	1-3/day	4 months	Automated SMS + family alerts + monitor follow-up	Monitor outreach	Dose time reminders, motivational cues, connectivity checks
Bediang (2018)	SMS via web-based platform	Daily	6 months	Neutral reminder messages; motivational, rotating	Congratulatory biweekly messages	"Don't forget," "Congrats on week X," motivational messages
Charalambous (2024)	Pill box + visual/audio alert	Daily	6 months + 12 months follow-up	Differentiated care (SMS, phone call, home visit)	Motivational counselling, data review with patient	SMS reminders after missed dose, data feedback at monthly visits
Fang (2017)	Manual SMS via telecom network	Daily	Full 6-month treatment	Core education + habit reinforcement	N/A	Medication reminders, re-examination prompts, hygiene advice
Gashu (2021)	Web-based system with text + graphic SMS	Daily medication + weekly refill	4-month continuation phase	One-way reminders + initial orientation	None specified	Graphic-based pill reminders and refill alerts in local language
Johnston (2018)	Two-way SMS check-in	Weekly	Up to 6 or 12 months (LTBI)	Passive engagement + follow-up call	Call if response negative or absent	Weekly wellness check-in ("Are you OK?")
Liu (2015)	SMS and MERM (pillbox)	Daily	Full treatment course	SMS (1–3/day) + pillbox alerts	Monthly provider data review	SMS: generic dose reminders, health info
Louwagie (2019)	SMS + MI	2×/week SMS + monthly MI	3 months of MI + 6-month tracking	Patient-directed prioritization of risk behaviours	Lay health worker support	SMS: motivational cues for adherence, drinking, smoking
Manyazewal (2022)	Digital pillbox audio + visual alerts	Daily	Full 2-month intensive phase	Self-administered therapy with device alerts	Pillbox refill check + data download	Onboard LED & buzzer alerts; refill reminders
Mohammed (2016)	2-way SMS (Zindagi SMS)	Daily	Entire 6–8 months treatment	Motivational SMS + engagement tracking	Phone calls for 7-day non-response + $ reimbursement	"Your health is in your hands…" (motivational); no TB mention
Wei (2024)	MERM (pillbox) + Application (WeChat)	Daily	6–7 months with monthly analysis	Real-time data review + family + provider feedback	Video-observed therapy if ≥3 missed doses + free mobile data	Voice prompts, dose tracking, communication tools

Note: MERM= Medicine Event Reminder Monitor; LTBI= latent TB infection; MI= motivational interview; SMS= Short message service.

Risk of Bias

Figure 2 shown RoB 2 summary among the 11 studies, three employed a cluster randomized controlled trial design (Charalambous et al., 2024; Fang et al., 2017; Liu et al., 2015), while the remaining eight were individually randomized RCTs. Overall, the majority of studies exhibited some concerns regarding bias, with only one study rated as low risk across all domains (Mohammed et al., 2016). D1 (bias arising from the randomization process) was generally rated as low risk, except for Fang (2017), which showed some concerns. For cluster RCTs, D1b (bias due to timing of identification or recruitment of participants) was applicable and revealed some concerns in all three cluster studies. D2 (bias due to deviations from intended interventions) and D3 (bias due to missing outcome data) frequently showed some concerns, with two studies rated as high risk in D4 (bias in measurement of the outcome) (Fang et al., 2017; Gashu et al., 2021). Domain 5 (bias in selection of the reported result) was consistently rated as low risk across most studies. Overall, the RoB 2 was rated as "some concerns" in eight studies, while two studies were judged to have a high risk of bias (Fang et al., 2017; Gashu et al., 2021).

Figure 2. Risk of bias 2 summary



Quality Assessment

According to GRADE framework of the quality of evidence for treatment adherence and completion was low in overall. Only in one subgroup, LMICs in adherence was moderate, the remaining subgroups were low (Table 4).

Table 4. GRADE framework summary

Outcomes	Subgroup	No of studies	No. of participants (Intervention/ control)	Pooled effect size [95 % CI]	p-value for pooled	p-Value for heterogeneity	I²(%)	Quality of Evidence
Adherence	Overall	6	688/577	1.97 (1.05, 3.69)	0.04	<0.001	85%	⊕◯◯◯
	UMIC	4	521/427	1.87 (0.81, 4.36)	0.14	0.53	91%	⊕◯◯◯
	LMIC	2	167/150	1.97 (1.16, 3.35)	0.01	<0.001	0%	⊕⊕⊕◯
Completion	Overall	9	2137/2095	1.57 (1.08, 2.27)	0.02	<0.001	75%	⊕◯◯◯
	HIC	1	135/154	0.85 (0.50, 1.44)	0.55	NA	NA	⊕◯◯◯
	UMIC	4	705/703	1.95 (0.89, 4.29)	0.10	0.005	77%	⊕◯◯◯
	LMIC	4	1297/1238	1.74 (0.93, 3.27)	0.08	<0.001	83%	⊕◯◯◯

Noted: HIC= High-Income Country; UMIC= Upper Middle-Income Country; LMIC= Low Middle-Income Country; NA= not applicable.

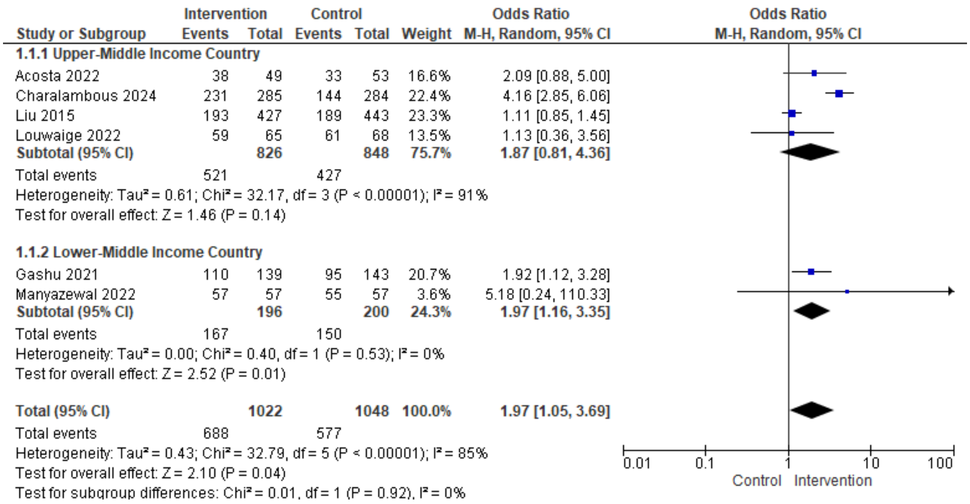
Effects on Adherence

In Figure 3, the overall pooled OR across six studies (N = 1.265 participants) were 1.97, 95% CI [1.05, 3.69], p = 0.04, indicating a -significant trend towards improved adherence with ERS (see Figure 3). A high heterogeneity was observed across studies, I^2 = 85%, χ^2 (5) = 32.79, p < .001.

Subgroup analyses were performed based on country income level. ERS were significantly improved TB treatment adherence in low- and middle-income countries (LMICs) on two studies with 396 participants (OR = 1.97, 95% CI [1.16, 3.35], p = 0.01), with no heterogeneity (I^2 = 0%, χ^2 (1) = 0.40, p = 0.53), while among four studies in upper-middle income countries (UMICs) with 688 participants, the pooled OR was 1.87 (0.81, 4.36), p = 0.14, with high heterogeneity (I^2 = 91%, χ^2 (3) = 32.17, p < .001) (Figure 3).

The test for subgroup differences yielded a non-significant result (χ^2 (1) = 0.01, p = 0.92, I^2 = 0%), indicating no statistically significant difference in effect sizes between UMICs and LMICs on treatment adherence (Figure 3).

Figure 3. Forest Plot of Adherence

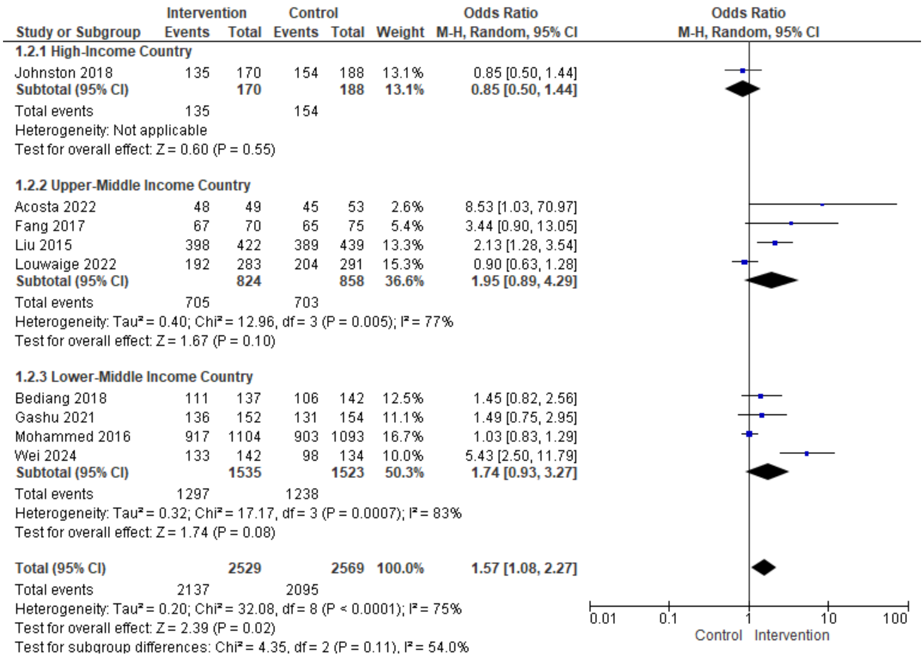


Effects on Completion

The forest plot of nine studies (N= 4,232) analysed the effect on TB treatment completion. Overall, ERS were a significantly meaningful to improve treatment completion among TB patients (OR = 1.57, 95% CI [1.08, 2.27], p = 0.020), with significant heterogeneity across studies (I^2 = 75%, τ^2 = 0.20, χ^2 = 32.08, df = 8, p < .001) (Figure 4).

Subgroup analyses revealed a not significant effect sizes, either in LMICs (OR = 1.74, 95% CI [0.93, 3.27], p = 0.08), UMICs (OR = 1.95, 95% CI [0.89, 4.29], p = 0.10), and high-income countries (HICs) (OR = 0.85, 95% CI [0.50, 1.44], p = 0.55). A high heterogeneity was substantial within UMICs (I^2 = 77%) and LMICs (I^2 = 83%) subgroups. The test for subgroup differences test yielded a not statistically significant (I^2 = 54%, χ^2 = 4.35, df = 2, p = 0.11), suggesting no statistically significant difference in effect sizes between UMICs, LMICs, and HICs (Figure 4).

Figure 4. Forest Plot of Completion



Discussion

This first systematic review and meta-analysis provides evidence from randomized controlled trials provides evidence that electronic reminder systems (ERS) significantly improve both treatment adherences (OR = 1.97, 95% CI [1.05, 3.69], *p* = 0.04) and treatment completion rates (OR = 1.57, 95% CI [1.08, 2.27], *p* = 0.020) among TB patients. The pooled results from 11 studies demonstrate that ERS significantly improve both treatment adherence (OR = 1.97, 95% CI [1.05, 3.69], p = 0.04) and treatment completion rates (OR = 1.57, 95% CI [1.08, 2.27], p = 0.020) among TB patients. These findings affirm the potential of technology-based interventions as a valuable adjunct to standard TB care. The consistent direction of effect across most included studies strengthens the robustness of this conclusion, suggesting that ERS can play a crucial role in addressing the persistent challenge of suboptimal treatment outcomes in TB control programs (Huda et al., 2024).

Subgroup analyses revealed critical contextual insights. The adherence-enhancing effect of ERS was statistically significant in LMICs (OR = 1.97), with no heterogeneity, suggesting that ERS may be particularly valuable in resource-constrained settings where structural barriers to care are pronounced (Eze et al., 2021). This consistency likely reflect the high unmet need for adherence support and the widespread availability of mobile phones, even in rural LMICs (Alnasser et al., 2025). However, the absence of heterogeneity in the LMIC adherence subgroup (I^2 = 0%) may reflect the smaller number of studies (n = 2) and similar intervention approaches, though this also reduces confidence in the stability of the estimate (Lensen, 2023). In contrast, studies from UMICs showed a non-significant trend toward improved adherence (OR = 1.87, p = 0.14) with 91% of substantial heterogeneity, possibly due to variability in ERS modalities [e.g., SMS with/out pillbox (Liu et al., 2015; Louwagie et al., 2022), voice call (Charalambous et al., 2024), and monitor follow-up (Acosta et al., 2022)], as well as health system infrastructure, or measurements (Sandi et al., 2024). Despite these differences, the test for subgroup differences yielded no statistically significant difference between UMICs and LMICs (p = 0.92) suggesting that ERS may confer similar relative benefits across income strata, their absolute impact is modulated by local context.

For treatment completion, the pooled effect across all income levels statistically significant (OR = 1.57), even though no reached a significance in each subgroup (e.g., LMICs, UMICs, or HICs. This pattern aligns with recent evidence indicating moderate-certainty benefits of digital adherence technologies for TB completion, albeit with considerable variability in intervention fidelity and outcome definitions (Huda et al., 2024). Notably, the point estimate in HICs was less than 1.0 (OR = 0.85) may reflect ceiling effects, where baseline completion rates are already high due to robust health systems, thereby limiting the marginal benefit of ERS (Bagyawantha et al., 2025; Hossain et al., 2025). Unlike adherence, treatment completion, being a more definitive and binary outcome, may be less sensitive to variations in health system infrastructure and patient behaviour, which is often measured more granularly and subject to daily fluctuations (Ridho et al., 2022). The non-significant subgroup differences across HICs, UMICs, and LMICs (p=0.11) for treatment completion, it indicated the broader applicability of ERS when integrated into structured prevention programs (Louw et al., 2024). In these contexts, persistence to complete may be due to complex factors such as medication efficacy consideration, mental health, or socioeconomic stability, which are barriers that can be overcome with ERS.

The observed efficacy of ERS in LMICs aligns with prior research indicating that digital health interventions can be particularly impactful in resource-constrained settings where structural barriers, such as limited healthcare access, fragmented follow-up systems, and patient-level socioeconomic challenges undermine treatment continuity (Erku et al., 2023; McCool et al., 2022). In such contexts, even simple SMS-based reminders may serve as critical touchpoints that reinforce patient engagement and compensate for weak health system infrastructure. Conversely, the lack of significant benefit in HICs may reflect already high baseline adherence due to robust healthcare systems, greater patient education, and more accessible clinical support, thereby diminishing the incremental value of ERS (Louw et al., 2024). This interpretation is consistent with the "law of diminishing returns" in digital health interventions, where benefits are most pronounced in settings with the greatest unmet needs (Pawson et al., 2016).

Despite the significant pooled effect on treatment adherence and completion, substantial heterogeneity was observed across studies (I^2 = 75% for completion; I^2 = 85% for adherence) warrants cautious interpretation. This variability likely arises from differences in study design (e.g., cluster vs. individual randomization), population characteristics, ERS modalities (SMS, apps, voice calls), message frequency, personalization, and outcome measurement (Higgins & Eldridge, 2023; Sandi et al., 2024). Such methodological diversity limits the generalizability of pooled estimates and highlights the need for standardized reporting of digital intervention components and adherence metrics in future trials (Lensen, 2023). From a theoretical perspective, ERS likely operate by providing external cues that bridge the intention–behaviour gap, according to the Health Belief Model theory, the ERS's function as environmental prompts within health seeking behaviour capability through increasing cues to action and individual awareness (Rosenstock et al., 2016; Zhou et al., 2025), primarily enhancing opportunity and acting as a compensatory mechanism for limited healthcare access. The mechanism is plausibly rooted in behavioural science; reminders serve as cues to action, bridging the intention-behaviour gap and fostering habit formation (Conner & Norman, 2022). In LMICs, where structural opportunity is often constrained, such cues may be especially effective (McCool et al., 2022). However, the lack of effect in HICs suggests that reminders alone may be insufficient without addressing deeper motivational or capability-related barriers, such as health literacy.

From a practical and policy standpoint, these results support the integration of ERS into TB care programs in LMICs, where they may serve as cost-effective, scalable tools to improve treatment outcomes. Given the global push toward TB elimination, digital adherence technologies could partial substitute for directly observed therapy (DOT) strategies, particularly in decentralized or community-based care models (Manyazewal et al., 2023). However, policymakers should exercise caution in extrapolating these findings to HICs and UMICs, where alternative strategies targeting psychosocial or systemic barriers may be more appropriate. Future research should prioritize head-to-head comparisons of ERS modalities, cost-effectiveness analyses, and process evaluations to identify the core components that drive success across diverse health systems.

Limitations

This review has several limitations that should be considered when interpreting the findings. First, the included studies exhibited substantial heterogeneity in intervention design, delivery methods (e.g., SMS, voice calls, mobile apps), duration, and frequency of reminders. This variability limits the ability to draw definitive conclusions about which specific types of electronic reminders are most effective. Second, there was considerable methodological heterogeneity in how adherence and completion term were defined and measured.

Conclusions

This meta-analysis provides evidence that ERS interventions significantly improve TB treatment adherence and completion among TB patients, with the most consistent benefits observed in LMICs where health system constraints are greatest. Despite substantial heterogeneity in the underlying evidence, the overall direction and magnitude of effect support the strategic integration of ERS into national TB control programs as a scalable, low-cost digital health intervention. However, in high-income setting with already robust care systems, standalone reminders offer limited added value. Policymakers should therefore adopt a differentiated approach prioritizing ERS deployment in resource-limited settings while embedding them within multifaceted support strategies in more advanced health systems. Future research should focus on optimizing intervention design, improving implementation fidelity, and tailoring strategies to local contexts to enhance the effectiveness of digital adherence technologies in TB programs.

Conflict of Interest

The authors declare that they have no competing interests

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