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The Role of Nursing Technology in Digital Transformation for Tuberculosis Patient Care: Literature Review

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ABSTRAK

Tuberkulosis (TB) merupakan masalah kesehatan global yang diperburuk oleh faktor sosial, budaya, dan ekonomi seperti stigma, keterbatasan akses, serta kondisi ekonomi yang sulit, yang berdampak pada rendahnya kepatuhan pengobatan. Transformasi digital dalam keperawatan melalui telemedicine, telenursing, dan mHealth muncul sebagai solusi untuk meningkatkan pemantauan dan hasil klinis pasien TB. Literature review dengan pendekatan PRISMA-ScR dilakukan untuk mengidentifikasi penelitian mengenai peran teknologi digital dalam meningkatkan kualitas pelayanan kesehatan pasien TB. Data dikumpulkan dari Google Scholar, ResearchGate, dan Mendeley dengan kriteria inklusi tahun 2021–2025. Analisis 12 artikel mengungkapkan bahwa intervensi digital, seperti telenursing melalui SMS/WhatsApp, aplikasi mHealth, dan sistem pemantauan elektronik, efektif meningkatkan kepatuhan pengobatan serta pemantauan kondisi pasien. Aplikasi mHealth menyediakan pengingat obat dan edukasi kesehatan, sedangkan sistem digital memungkinkan pemantauan real-time oleh tenaga kesehatan. Transformasi digital berkontribusi signifikan dalam meningkatkan kepatuhan pengobatan dan kualitas pelayanan bagi pasien TB, meskipun tantangan seperti akses teknologi, literasi digital, dan kesiapan infrastruktur perlu diatasi. Kebijakan yang mendukung akses dan literasi digital serta pengembangan strategi teknologi yang inklusif dan berkelanjutan sangat diperlukan untuk optimalisasi pengobatan TB dan mendukung upaya eliminasi penyakit di masa depan.

Kata Kunci: Telenursing, Tuberculosis, Medication Adherence, mHealth Applications, Treatment Compliance.

ABSTRACT

Tuberculosis (TB) is a global health issue exacerbated by social, cultural, and economic factors such as stigma, limited access, and challenging economic conditions, which lead to poor treatment adherence. Digital transformation in nursing through telemedicine, telenursing, and mHealth has emerged as a solution to improve patient monitoring and clinical outcomes. A literature review using the PRISMA-ScR approach was conducted to identify studies on the role of digital technology in enhancing healthcare quality for TB patients. Data were collected from Google Scholar, ResearchGate, and Mendeley with inclusion criteria for the years 2021–2025. Analysis of 12 articles revealed that

digital interventions, including telenursing via SMS/WhatsApp, mHealth applications, and electronic monitoring systems, effectively improve treatment adherence and patient monitoring. mHealth apps provide medication reminders and health education, while digital systems allow real-time monitoring by healthcare providers. Digital transformation significantly contributes to improving treatment adherence and healthcare quality for TB patients, although challenges such as technology access, digital literacy, and infrastructure remain. Supportive policies for digital access and literacy, along with the development of inclusive and sustainable technological strategies, are essential for optimizing TB treatment and advancing TB elimination efforts.
Keywords: *Telenursing, Tuberculosis, Medication Adherence, mHealth Applications, Treatment Compliance.*

INTRODUCTION

Tuberculosis (TB) is an infectious disease caused by Mycobacterium tuberculosis, primarily affecting the lungs and contributing to high morbidity and mortality rates (Hidayat et al., 2024). It is also one of the leading causes of death from infectious diseases worldwide, with an increased risk of mortality, recurrence, and drug resistance due to poor medication adherence (Chen et al., 2023).

More than 10 million people continue to contract tuberculosis (TB) annually, and the number has been increasing since 2021. The estimated global incidence of TB in 2023 reached 10.8 million cases. Of these, 55% were adult men (≥15 years) with 6.0 million cases, 33% were adult women with 3.6 million cases, and 12% were children and young adolescents (0–14 years) with 1.3 million cases. The majority of TB cases occur in high-burden countries, with eight nations accounting for more than two-thirds of the global total: India (26%), Indonesia (10%), China (6.8%), the Philippines (6.8%), Pakistan (6.3%), Nigeria (4.6%), Bangladesh (3.5%), and the Democratic Republic of the Congo (3.1%) (World Health Organization, 2024).

Most TB patients can be cured with available treatments; however, these treatments require strict adherence for at least six months, or even up to two years for drug-resistant TB (MDR-TB) cases. TB control strategies focus on early detection and treatment completion. However, many patients struggle with adherence, leading to premature treatment discontinuation, increasing the risk of drug resistance, treatment failure, recurrence, and mortality (Aisyah et al., 2020).

Digital-based TB care management has been implemented in Indonesia to enhance patient adherence and prevent Multi-Drug Resistant Tuberculosis (MDR-TB). Research indicates that interventions such as digital treatment supervision, including Directly Observed Treatment Short-Course (DOTS) using Video Observed Therapy (VOT), phone-based medication refill reminders, and treatment monitoring through digital applications, have been employed. Additionally, individualized education and psychological counseling approaches have been used to improve patient self-management. The role of healthcare workers in motivating and

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monitoring patients through text messages or phone calls has also contributed to increased treatment adherence. Factors such as age, attitude, marital status, and living conditions influence the effectiveness of patient self-management, while knowledge and attitudes toward TB play a crucial role in treatment success. With this digital approach, treatment success rates are expected to improve, and MDR-TB cases can be minimized (Minggarwati et al., 2023).

In the context of tuberculosis (TB), a global health challenge, digital technology plays a crucial role. The use of telemedicine and connected medical devices allows for remote patient monitoring, ensuring adherence to treatment regimens and enabling early intervention in case of complications. Moreover, integrated health information systems facilitate interprofessional collaboration among doctors, nurses, and other healthcare professionals in designing comprehensive care strategies for TB patients (Putra et al., 2022).

To enhance healthcare service effectiveness, service innovations must be developed with a focus on providing convenience for TB patients during treatment (Hidayat et al., 2024). Digital transformation in nursing has proven to improve the quality of care for TB patients through the use of telemedicine, electronic medical records, and mobile health applications. These technologies enable real-time monitoring and effective communication between patients and healthcare providers, thereby supporting medication adherence. Despite challenges such as infrastructure limitations and data security concerns, digital integration has been shown to enhance healthcare service effectiveness (Khatimah et al., 2024).

However, the adoption of digital technology also faces several challenges and issues (Nugroho et al., 2023). Socio-cultural factors influence the effectiveness of digital health technologies. Low digital literacy, preferences for face-to-face interactions, and familiarity with technology play a role in the successful implementation of such innovations (Hutagalung et al., 2024). In addition to socio-cultural aspects, economic factors such as income levels and access to technological devices are significant determinants. Individuals with financial limitations may struggle to secure stable internet connections, restricting their ability to utilize digital health technology. Furthermore, additional costs associated with technology use, such as internet data, may pose a barrier for economically disadvantaged groups (Ngafifi, 2014).

WHO's TB programs leverage digital applications such as short message service (SMS) reminders, video-supported therapy (VOT), and electronic medication monitoring (EMM) devices to help patients complete treatment and enable healthcare providers to track daily doses and treatment progress (Farhana et al., 2022). A study by Fuadiati (2023) provides evidence that digital technology plays a significant role in improving TB patient care by enhancing medication adherence, facilitating communication between patients and healthcare providers, and promoting self-management. However, there remains a lack of research comparing the effectiveness of different methods, as well as limited studies exploring how socio-cultural factors influence technology adoption.

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Based on the discussion above, the research question for this study is: "How does digital technology contribute to improving the quality of healthcare services for pulmonary TB patients?" The objective of this literature review is to analyze the extent to which digital technology enhances monitoring, treatment adherence, and clinical outcomes for TB patients. This review also aims to explore various digital-based interventions, such as telemedicine, telenursing, mobile health (mHealth) applications, and electronic medication monitoring (EMM) devices, that have been implemented to support TB treatment.

Additionally, this study focuses on the effectiveness of digital technology in addressing key challenges in TB treatment, such as limited access to healthcare facilities, low patient adherence, and delayed detection of drug side effects. By understanding the impact of digital technology on TB management, the findings from this literature review are expected to serve as a foundation for developing more effective strategies to improve healthcare service quality for TB patients, particularly in high-burden countries.

RESEARCH METHODS

This study employs a literature review method, which involves analyzing various sources of literature. The objective of this analysis is to summarize and synthesize findings from existing research to generate new insights or perspectives based on previous studies. This literature review follows the PRISMA Extension for Scoping Reviews (PRISMA-ScR) framework to identify interventions utilizing technology, particularly telenursing and telehealth, in improving the quality of healthcare services for pulmonary TB patients undergoing treatment. The research question in this study is: "Can technology-based nursing interventions enhance the quality of healthcare services for pulmonary TB patients?"

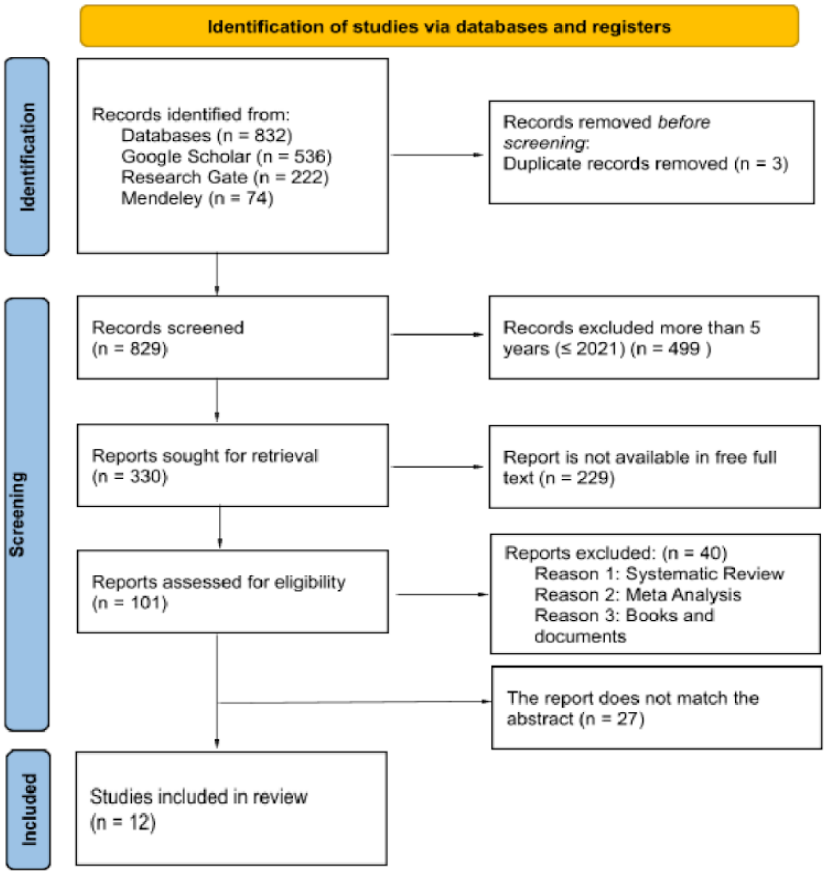
For the literature search, three databases were used: Google Scholar, ResearchGate, and Mendeley. The keywords used to search for journal publications were telenursing, tuberculosis, medication adherence, mHealth applications, and treatment compliance. The criteria for this study, based on the PICO (Patients, Interventions, Comparison, Outcome) framework, are as follows:

1. Problem/Patients: Tuberculosis (TB) patients receiving healthcare and nursing services.
2. Intervention: Implementation of digital technology in nursing, such as telenursing, health applications, digital monitoring systems, or artificial intelligence (AI)-based tools to enhance TB patient care.
3. Comparison: No Comparison.
4. Outcome: Improvement in healthcare service quality, including patient adherence to treatment, efficiency in patient condition monitoring, and better clinical outcomes for TB patients.

Based on the inclusion criteria, the sources considered in this scoping review consist of all types of quantitative and qualitative studies that focus on telenursing or health applications as interventions for pulmonary tuberculosis patients receiving healthcare or nursing services. We limited the literature search period to the last five years (2021–2025), including articles in English and Indonesian that are available in full-text format. The exclusion criteria for this literature review include studies using secondary data (review articles). The selected published articles, based on the inclusion and exclusion criteria, were extracted and analyzed by considering the title, citation, country, population, sample and sampling techniques, theory or concept, variables, instruments, results, and the strengths and weaknesses of the journal articles.

The data analysis approach used in this study is quantitative. All authors read the selected articles, summarized them, and entered the information into a data extraction table. Then, the authors discussed the findings and compiled the research results. Next, the authors classified digital technology interventions based on similar methods. A narrative description was then created to explain the interventions using digital technology. All authors completed the study selection process, and the included studies followed the PRISMA flow diagram:

PRISMA



Gambar 1. Diagram Prisma

RESULTS AND DISCUSSION

The identification process of articles from the three e-databases resulted in 832 research articles (536 articles from Google Scholar, 222 articles from ResearchGate, and 74 articles from Mendeley). A screening process was conducted by removing 3 duplicate articles. Next, 499 articles were excluded as they were older than 5 years (≤ 2021). This left 330 articles for further selection. However, 229 articles were not available in full-text format for free, leaving only 101 articles for eligibility assessment. Of these, 27 articles were excluded due to irrelevance based on abstract review. Finally, 12 selected articles were included in the review, summarized, and presented in a table format.

In this study, digital transformation in nursing is utilized to improve the quality of healthcare services for tuberculosis patients through various technology-based interventions. Among the 12 selected articles, 5 articles discuss the use of short message service (SMS) and WhatsApp-based telenursing, 4 articles focus on mobile health (mHealth) applications, and 3 articles explore digital adherence technologies based on voice and interactive applications. The research designs in these 12 articles consist of 4 quasi-experimental studies, 3 randomized controlled trials (RCTs), 2 pre-post studies, 2 retrospective studies, and 1 process evaluation study. The research was conducted in Indonesia, China, Vietnam, Uganda, and India.

Tabel 1. Summary of Articles Relevant to Digital Transformation in Nursing: The Role of Technology in Improving the Quality of Health Care for Patients with TB

No.	Article Title, Author & Year	Research Objectives	Population, Sample & Sampling Technique	Type of Research	Result
1.	Telehealth Reduces Missed Appointments in Pediatric Patients with Tuberculosis Infection (Zhao A, et al., 2022)	This study aims to identify factors contributing to the high rate of appointment nonattendance and failure to complete therapy in pediatric patients with tuberculosis infection (TBI). In addition, this study also evaluates the impact of the COVID-19 pandemic and telehealth implementation on appointment no-show rates in pediatric TBI patients.	**Population:** Pediatric patients aged 0-18 years referred to Yale Pediatric Winchester Chest Tuberculosis Clinic for TBI therapy. **Sample:** 129 pediatric patients referred to the clinic from 2016-2019 before telehealth implementation. 29 pediatric patients referred in 2021 after telehealth implementation. **Technique:** Retrospective review of medical records of patients who had been treated at the clinic.	This study is a retrospective study with a comparative analysis design before and after telehealth implementation.	Before telehealth was implemented, the appointment non-attendance rate for pediatric patients with TBI was 16.9%, influenced by language, service access and distance. Only 72.1% of patients completed therapy, with failure rates higher in Spanish-speaking patients and rifampin users. After telehealth was implemented in 2021, no-shows dropped to 5.8%, with 54% of visits conducted virtually, mainly by patients living far away. Telehealth was effective in improving appointment adherence, although its impact on therapy completion remains unclear.
2.	The Effect of Telenursing on	This study aims to assess the	**Population:** Pulmonary tuberculosis patients in	This research uses the Quasy -	This study showed that telenursing significantly

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	Adherence to Taking Medicine for Pulmonary Tuberculosis Patients (Mawarti H, Umaroh A.S, Mukhoirotin, 2023)	effect of telenursing on medication adherence in pulmonary TB patients, especially due to the decrease in health visits during the COVID-19 pandemic. Telenursing is used for remote education and monitoring to improve patient adherence.	the working area of Dukuhklopo Health Center, Jombang Regency. **Sample:** 20 respondents. **Technique:** Total sampling.	Experiment method with the Posttest Control Group Design.	improved medication adherence in pulmonary TB patients. The average adherence in the telenursing group reached 95, compared to 72.5 in the control group. 90% of patients in the telenursing group had high adherence, while the control group had only 60%. The Mann-Whitney test showed p = 0.02, confirming the effectiveness of telenursing as an efficient and accessible education and monitoring method.
3.	Effects of an mHealth Intervention for Pulmonary Tuberculosis Self-management Based on the Integrated Theory of Health Behavior Change: Randomized Controlled Trial (Bao Y, et al. 2022).	This study aimed to evaluate the effectiveness of an ITHBC-based mHealth intervention in improving selfmanagement of pulmonary TB patients, with a focus on disease awareness, social support, and treatment adherence.	**Population:** Pulmonary tuberculosis patients undergoing treatment at Harbin Chest Hospital, China. **Sample:** 114 consecutively recruited patients. **Technique:** Convenience sampling with random division into intervention group (59 patients) and control group (53 patients).	This study is a Randomized Controlled Trial (RCT) with a prospective design conducted from May to November 2020.	The results showed that ITHBC-based mHealth intervention significantly improved self-management of pulmonary TB patients. After three months, the intervention group showed improved disease awareness, self-efficacy, social support, and education satisfaction compared to the control group ($p < 0.001$). Self-management behavior scores also improved, except for covering the mouth when coughing and washing hands. This study concludes that this intervention can improve treatment adherence and the quality of pulmonary TB prevention and control.
4.	An mHealth App Technology to Strengthen Adverse Event Management of Multi-Drug-Resistant Tuberculosis in Vietnam: Protocol for a Process Evaluation of the V-SMART Trial (Nguyen H.B, et al. 2025).	This study aims to evaluate the implementation of an mHealth app for managing adverse drug events in MDRTB patients in Vietnam, focusing on its effectiveness, affordability, and constraints and opportunities for	**Population:** MDR-TB patients and health workers in seven provinces in Vietnam involved in the V-SMART trial. **Sample:** 903 participants enrolled in the trial. **Technique:** Combination of quantitative and qualitative methods with a purposive	This study was a process evaluation of a Randomized Controlled Trial (RCT) using mixed-methods involving quantitative analysis and qualitative interviews.	The results of this study show that the V-SMART mHealth app has the potential to improve MDR-TB side effect management, but user adoption and engagement rates are mixed. Patients and health workers find it helpful in monitoring and communication, but face barriers such as internet access, other communication preferences, and app interface. User engagement tends to

No.	Article Title, Author & Year	Research Objectives	Population, Sample & Sampling Technique	Type of Research	Result
		implementation in healthcare.	sampling approach for interviews and data analysis of app usage.		decrease over time and varies across provinces. This study emphasizes the need for improved app design, health worker training, and better integration within the healthcare system to increase the effectiveness and sustainability of mHealth.
5.	Application of N-SMSI (Ners-Short Message Service Intervention) Telenursing (Rahman et al., 2023)	This study aims to evaluate the effectiveness of the application of Telenursing Ners Short Message Service Intervention (N-SMSI) in improving compliance of pulmonary tuberculosis patients with post-treatment treatment. With increased adherence, a reduction in the risk of relapse, drug resistance, and wider transmission is expected.	**Population:** Pulmonary TB patients in the Ciamis Health Center Working Area in 2022. **Sample:** 32 patients with pulmonary tuberculosis. **Technique:** Total sampling, which is taking the entire population as a sample.	This study is a quasi-experiment with a one group pretest-posttest design. This method was used to assess the effectiveness of the N-SMSI intervention in improving treatment adherence of pulmonary TB patients at the Ciamis Health Center. Data were collected using the Morisky Medication Adherence Scale-8 (MMAS-8) questionnaire, and the results were analyzed using the Wilcoxon Signed Rank Test.	The results showed that the implementation of N-SMSI was effective in improving treatment adherence of post-treatment Pulmonary TB patients. With the SMS reminder program implemented for one month, patients were more disciplined in taking medication, and their compliance could be better monitored. In addition, patients felt more cared for by health workers, which contributed to improved adherence to treatment and reduced risk of family transmission.
6.	Effectiveness of A-Ba-Te Innovation (Let's Eradicate Tuberculosis) on Self-Care Management among TB Patients in Public Health Center (Hidayat et al., 2024)	The purpose of this study was to analyze the effectiveness of the A-Ba-Te (Ayo Basmi Tuberculosis) innovation in improving the self-care management skills of TB patients in the Sirampog Puskesmas working area. This innovation includes health education, breathing exercises, effective coughing	**Population:** Pulmonary TB patients who received services at Sirampog Health Center. **Sample:** 22 TB patients undergoing treatment at Sirampog Health Center. **Technique:** Purposive sampling, which selected TB patients	This study was a quasi-experiment with a one group pretest-posttest design. The study aimed to evaluate the effectiveness of the A-Ba-Te innovation in improving self-care management of TB patients. The intervention was	The study found that the A-Ba-Te innovation, which included health education, deep breathing exercises, effective coughing techniques, and medication reminders via WhatsApp, was effective in improving self-care management of TB patients. Statistical t-test results showed a significant difference before and after the intervention with a p value = 0.000, indicating

No.	Article Title, Author & Year	Research Objectives	Population, Sample & Sampling Technique	Type of Research	Result
		techniques, semi-Fowler position, and WhatsApp-based medication reminders.	who met the inclusion criteria for the study.	conducted for four weeks, including health education, deep breathing exercises, effective coughing techniques, and medication reminders via WhatsApp. Data were analyzed using an independent t-test to see differences before and after the intervention.	that this intervention contributed greatly to improving patients' compliance and awareness in managing their disease.
7.	Effect of Health Education with N-SMSI (Ners-Short Message Service Intervention) on Knowledge Tuberculosis Patient about Tuberculosis (Reni Asmara Ariga, Siti Zahara Nasution, Rina Amelia, 2022)	This study aims to improve the knowledge of TB patients through N-SMSI (Ners-Short Message Service Intervention) based education, which is a community nurse intervention with short messages about disease, treatment, prevention, and therapy adherence. In addition, the study measured its effectiveness in improving patient understanding and reducing treatment non-adherence.	**Population:** Pulmonary TB patients in Medan, Indonesia. **Sample:** 72 TB patients who were in the intensive phase of treatment. **Technique:** Total sampling, namely all TB patients who met the inclusion criteria at the Medan Johor Health Center and Medan Amplas Health Center.	This study is a quasi-experiment with a one group pretest-posttest design. The aim of the study was to determine the effect of N-SMSI-based health education on improving the knowledge of TB patients. The sample consisted of 72 patients at two health centers in Medan. Data were collected through questionnaires and analyzed using the Wilcoxon Signed Rank Test.	The results showed that the N-SMSI intervention significantly improved TB patients' knowledge of the disease and its treatment. Before the intervention, most patients had a fair level of knowledge (51.4%). However, after receiving two months of education via SMS, patients' knowledge level improved significantly, with 68.1% in the good category. Wilcoxon Signed Rank Test statistics showed a p value = 0.000, confirming that health education through N-SMSI plays an important role in improving patients' understanding of TB.
8.	The Influence of Telenursing against Adherence to Anti TB Treatment toward Tuberculosis Patient in BIMA City (Julhana, Awan Dramawan, A. Haris, Syaiful, 2021)	The results showed that the N-SMSI intervention significantly improved TB patients' knowledge of the disease and its treatment. Before the intervention, most patients had a fair level of knowledge (51.4%).	**Population:** Pulmonary TB patients in Bima City, West Nusa Tenggara. **Sample:** 60 TB patients at the Bima City Health Center. **Technique:** Total sampling, which is	This study was a quasi-experiment with a one group pretest-posttest design. This study evaluated the effect of SMS-based telenursing in improving TB	This study found that SMS-based telenursing significantly improved TB patients' adherence to anti-TB therapy. Before the intervention, only 23.3% of patients had moderate adherence and 76.7% had low adherence. After the intervention, all patients

No.	Article Title, Author & Year	Research Objectives	Population, Sample & Sampling Technique	Type of Research	Result
		However, after receiving two months of education via SMS, patients' knowledge level improved significantly, with 68.1% in the good category. Wilcoxon Signed Rank Test statistics showed a p value = 0.000, confirming that health education through N-SMSI plays an important role in improving patients' understanding of TB.	taking the entire population of TB patients in the study period.	patients' adherence to anti-TB therapy. The study was conducted in three health centers in Bima City with a sample of 60 patients. Measurement of adherence was carried out with Morisky Medication Adherence Scales (MMAS-8) before and after the intervention, then analyzed using the Wilcoxon Signed Rank Test.	(100%) achieved high adherence. Wilcoxon Signed Rank Test showed p = 0.001, which means there is a significant difference between before and after the intervention.
9.	Impact of a Mobile Phone-Based Interactive Voice Response Software on Tuberculosis Treatment Outcomes in Uganda (CFL-TB): a Protocol for a Randomized Controlled Trial (Byonanebye, et al., 2021).	This study aimed to evaluate the effectiveness of Call for Life-TB (CFL-TB), a mobile health intervention with interactive voice response (IVR), in improving tuberculosis (TB) treatment adherence and success in Uganda. By providing medication reminders, appointment alerts, and remote symptom reporting, CFL-TB seeks to improve adherence, retention in treatment, and cure rates among TB patients. The study also assessed the cost-effectiveness and acceptability of this digital intervention in a resource-limited setting.	**Population:** Patients with drug-susceptible TB receiving care at five public health facilities in Uganda. **Sample:** 274 patients, randomly assigned to the intervention group (CFL-TB users) or control group (standard care only) in a 1:1 ratio. **Technique:** Randomized controlled trial (RCT) with participants selected from public and rural TB treatment facilities.	This study used a study design method with a randomized controlled trial (RCT), multicenter with qualitative evaluation studies and nested economics.	This study hypothesized that Call for Life-TB (CFL-TB) would increase TB treatment success rates by at least 15% compared to standard care. The intervention provides daily adherence reminders, appointment alerts, and remote symptom reporting via interactive voice response (IVR) calls, allowing for better patient implementation and retention. The primary outcome of the program is treatment success at six months, measured through cure rates and treatment completion, while secondary outcomes include adherence rates, clinic attendance rates, cost-effectiveness, and stakeholder perceptions. If effective, CFL-TB could be a scalable mobile health solution to improve TB treatment adherence in low- and middle-income countries (LMICs) with a high TB burden and low literacy rates.

No.	Article Title, Author & Year	Research Objectives	Population, Sample & Sampling Technique	Type of Research	Result
10.	Impact of the 99DOTS digital adherence technology on tuberculosis treatment outcomes in North India: a pre-post study (Chen, et al., 2023).	This study aimed to evaluate the effectiveness of 99DOTS, a mobile phone-based digital adherence technology, in improving tuberculosis (TB) treatment outcomes in Himachal Pradesh, India. The intervention was designed to support medication adherence by encouraging patients to call a toll-free number after taking medication, allowing health workers to monitor adherence remotely. Although 99DOTS has been widely implemented across India, limited research has assessed its real-world impact on treatment success.	**Population:** Patients with drug-sensitive TB receiving treatment in the public health sector of Himachal Pradesh. **Sample:** The total sample consisted of the pre-intervention group (before 99DOTS): 7,722 patients who started treatment between February and October 2017. Post-intervention group (after 99DOTS): 8,322 patients who started treatment between July 2018 and March 2019. **Technique:** A pre-post design was used, where two groups of patients were compared before and after the implementation of 99DOTS technology in the treatment of tuberculosis (TB) in Himachal Pradesh, India.	This study used a pre-post design to evaluate the impact of implementing 99DOTS, a mobile phone-based digital technology, on tuberculosis (TB) treatment outcomes in Himachal Pradesh, India.	This study found no significant improvement in tuberculosis (TB) treatment outcomes after implementing 99DOTS in Himachal Pradesh, India. Good treatment outcomes remained similar between the pre-intervention (93.1%) and post-intervention (92.9%) groups (p = 0.758). Only 33% of patients in the post-intervention group used 99DOTS, with varying levels of adherence. Although those using 99DOTS had slightly better outcomes (94.8% vs. 92.0%), this may be due to patient selection factors rather than the intervention. Variability in adoption across districts suggests that local implementation and patient access to mobile technology influence effectiveness. These findings suggest that digital adherence technologies such as 99DOTS may not be universally effective and should be implemented in conjunction with other adherence support strategies, especially in areas with strong basic treatment programs.
11.	Effect of WhatsApp Chatbot Telenursing on Medication Adherence (Mulyati et al., 2024)	This study aimed to evaluate the effectiveness of WhatsApp chatbot-based telenursing in improving medication adherence among tuberculosis (TB) patients at Puskesmas Benteng, Sukabumi City. As non-adherence to TB treatment is a major cause of treatment failure (up to 50%), the intervention aimed to improve adherence through automated	**Population:** All TB-SO (drug-sensitive TB) and TB-RO (drug-resistant TB) patients undergoing treatment at Benteng Health Center, totaling 51 patients. **Sample:** 45 respondents, selected using total sampling based on inclusion and exclusion criteria. **Technique:** Pre-experimental design with one group pre-test post-test approach.	This study used a pre-experimental design with a one-group pre-test post-test approach. This involved measuring medication adherence before and after implementing a telenursing intervention via WhatsApp chatbot. Data were analyzed using	This study found that the implementation of WhatsApp chatbot-based telenursing significantly improved medication adherence in tuberculosis (TB) patients at Puskesmas Benteng, Sukabumi City. Before the intervention, only 9 out of 45 patients (20%) adhered to the prescribed anti-tuberculosis drug (OAT) treatment regimen. After receiving automated reminders via WhatsApp chatbot, adherence increased to 44 out of 45 patients (98%). Statistical analysis using the

No.	Article Title, Author & Year	Research Objectives	Population, Sample & Sampling Technique	Type of Research	Result
		reminders and patient engagement.		the Wilcoxon test to determine statistical significance..	Wilcoxon test yielded a p-value of 0.000 (<0.05), confirming a significant effect of the intervention. These findings suggest that WhatsApp chatbot telenursing is an effective tool for improving TB medication adherence and can be integrated into broader TB treatment and control programs to improve patient outcomes.
12.	The Effectiveness of Telenursing Program on Medication Adherence in Pulmonary Tuberculosis Patients Undergoing Outpatient Treatment at PIDIE District Hospital (Mahdani & Andriani, 2022).	This study aims to evaluate the effectiveness of a telenursing program in improving medication adherence in pulmonary tuberculosis (TB) patients undergoing outpatient care. TB treatment requires strict adherence over a long period of time, and non-adherence can lead to drug resistance, treatment failure, and relapse. Telenursing, which involves remote nursing interventions through telecommunication technology, was used to provide medication reminders and support through the WhatsApp platform. This study assessed whether this intervention improved adherence rates compared to standard care.	**Population:** 420 pulmonary TB outpatients at PIDIE District Hospital, Indonesia. **Sample:** 200 patients, selected using purposive sampling based on age (35-65 years), outpatient status, and willingness to participate. **Technique:** Quasi-experimental with Control Group Design, comparing patients receiving telenursing intervention with a control group with standard care.	This quasi-experimental study used a Control Group Design to evaluate the impact of telenursing on medication adherence in pulmonary TB outpatients at PIDIE Regional General Hospital, Indonesia. A purposive sample of 200 patients was selected based on age (35-65 years) and outpatient status. Conducted from August 15 to September 22, 2022, the intervention group received WhatsApp-based telenursing support for three months, while the control group received standard care. Medication adherence was measured before and after the intervention using	This study found that telenursing significantly improved medication adherence among pulmonary tuberculosis (TB) outpatients. In the intervention group, adherence was initially low (MMAS score of 1.45) but significantly improved to 2.74 after receiving WhatsApp-based nursing reminders and support for three months. In contrast, the control group showed a slight decrease in adherence from 1.55 to 1.42, indicating no significant improvement. Statistical analysis confirmed a significant difference in adherence in the intervention group (t-value: 24.005 > 1.984, p = 0.000), whereas there was no significant change in the control group (t-value: 1.812 < 1.984, p = 0.067). These findings suggest that telenursing is an effective strategy for improving TB medication adherence and can be integrated into routine treatment programs to improve patient outcomes.

No.	Article Title, Author & Year	Research Objectives	Population, Sample & Sampling Technique	Type of Research	Result
				the Morisky Medication Adherence Scale (MMAS), and t-test was used for statistical analysis.	

DISCUSSION

Short Message Service

According to Mwansa-Kambafwile et al. (2022), Short Message Service (SMS) is a text-based messaging method used to send reminders and notifications to tuberculosis (TB) patients to improve their treatment adherence. SMS has been proven effective in accelerating treatment initiation time and increasing patient compliance with prescribed treatment schedules. One form of SMS implementation in nursing is the Nurse Short Message Service Intervention (N-SMSI), a program that utilizes SMS to provide medication reminders, health education, and monitoring of tuberculosis patients' adherence to treatment (Ariga et al., 2022).

A study by Rahman et al. (2023) at the Ciamis Public Health Center found that implementing N-SMSI increased patient adherence to medication. The Wilcoxon statistical test showed an increase in adherence scores from an average of 4.38 before the intervention to 5.66 after the intervention ($p = 0.001$). The SMS messages contained medication schedule reminders and TB-related education, helping patients become more disciplined and feel cared for by healthcare providers.

Another study by Ariga et al. (2022) in Medan examined the effect of N-SMSI on improving TB patients' knowledge. Using a quasi-experimental method on 72 respondents, the study found that before the intervention, only 51.4% of patients had adequate knowledge about TB, whereas after receiving education through SMS, the percentage of patients with good knowledge increased to 68.1% ($p = 0.000$).

Meanwhile, a study conducted in Bima by Julhana et al. (2021) found that before receiving SMS reminders, 76.7% of patients had low adherence to TB treatment. However, after a two-month intervention, all patients achieved high adherence (100%), with statistical test results showing a significant difference ($p = 0.001$). In addition to Short Message Service (SMS) that uses pure SMS through mobile phones, there is also SMS utilizing WhatsApp services, as seen in a study by Mulyati et al. (2024). This research showed that using telenursing through a WhatsApp chatbot significantly improved medication adherence after the intervention. Before the intervention, only 9 out of 45 patients (20%) were adherent, but after the intervention, adherence

increased to 44 patients (98%). The Wilcoxon test showed a p-value of 0.000 (<0.05), indicating that the WhatsApp chatbot intervention had a significant impact on TB treatment adherence.

This finding aligns with research conducted by Mahdani & Andriani (2022), which found that the telenursing program significantly increased TB patients' medication adherence. Before the telenursing intervention, the average adherence score in the intervention group was 1.45, while after the intervention, it increased to 2.74. Statistical tests showed a significant difference in adherence before and after the intervention (t-value: 24.005 > 1.984, p = 0.000). Conversely, in the control group, adherence slightly decreased (t-value: 1.812 < 1.984, p = 0.067), indicating no significant change.

Short Message Service (SMS) in telenursing interventions for TB patients works by sending scheduled text messages as reminders to ensure medication adherence. These messages include medication schedule reminders, education about TB, and important treatment-related information and are sent through conventional telecommunications networks that do not require an internet connection. This allows messages to be received by a variety of mobile phones, including both smartphones and non-smartphones.

In practice, SMS messages are sent automatically through an SMS gateway system or manually by healthcare workers according to a pre-agreed schedule. Some interventions use free messaging packages or subsidies to reduce costs for patients. This advantage makes SMS easily accessible and independent of stable internet connections. However, SMS has a character limit, so information must be simplified and is often one-way, though efforts have been made to incorporate interactive features.

Based on various studies conducted, it can be concluded that the use of Short Message Service (SMS) in telenursing has proven effective in improving TB patients' medication adherence. This intervention not only provides medication schedule reminders but also serves as an educational medium that enhances patients' understanding of TB and its prevention. With its relatively low cost and high accessibility, N-SMSI is an innovative solution that supports the success of TB therapy and prevents drug resistance. It is also worthy of further development in healthcare systems. Moreover, the success of this intervention is supported by the community's familiarity with technology usage, whether through mobile SMS or WhatsApp applications. People tend to be more familiar with using this technology as they frequently incorporate it into their daily lives.

Electronic Medication Monitor (EMM)

The Electronic Medication Monitor (EMM) is a digital technology that monitors tuberculosis (TB) patients' adherence to treatment. Using electronic sensors, EMM records the time and frequency of patients' access to medication containers, allowing healthcare providers to monitor compliance in real-time. This technology effectively enhances patient discipline in undergoing long-term therapy, prevents drug resistance, and improves treatment outcomes. The

implementation of EMM in developing countries has the potential to support TB treatment success and disease elimination efforts (Farhana et al., 2022).

A study by Zhao et al. (2022) showed that the application of telehealth reduced the absence rate of pediatric TB patients from 16.9% to 5.8%. Telehealth improves service access for patients with geographical and language barriers and enables healthcare providers to detect non-compliance earlier for immediate intervention. Meanwhile, research by Mawarti et al. (2023) revealed that telenursing increased pulmonary TB patients' medication adherence to 95%, compared to 72.5% in the control group. Continuous communication through telenursing has proven effective in providing education and motivation to patients.

On the other hand, Bao et al. (2022) highlighted the effectiveness of behavioral theory-based mHealth applications in improving self-management among pulmonary TB patients. Patients using this application experienced increased disease awareness, self-efficacy, and social support. Additionally, Nguyen et al. (2025) discussed mHealth applications for monitoring adverse drug effects in MDR-TB patients, despite challenges related to technology access and user engagement. Overall, digital technology in nursing has great potential to enhance TB treatment adherence. However, its effectiveness requires a holistic approach, considering accessibility, patient education, and the sustainability of healthcare systems.

Patient adherence monitoring in tuberculosis (TB) treatment is also conducted through interactive voice response (IVR), as studied by Mirembe et al. (2021). The study utilized a technology called Call for Life-TB (CFL-TB), designed to improve treatment adherence by providing appointment reminders, educational messages, adherence alerts, and more. The study found that CFL-TB led to a 15% increase in treatment success rates in the intervention group compared to standard care (control group).

However, another study by Chen et al. (2023) found conflicting results, indicating no statistically significant difference in treatment outcomes between pre- and post-intervention groups (93.1% vs. 92.9%). This study focused on 99DOTS technology, which provides a method for monitoring TB treatment adherence through daily phone calls, automatic dose recording, reminders, and more. Among the post-intervention group, only 33% made at least one call to 99DOTS, with significant variations in call frequency. Further analysis also showed no significant differences in treatment outcomes between those who used 99DOTS and those who did not.

The success of the Electronic Medication Monitor (EMM) in enhancing medication safety does not solely depend on technical aspects but is also influenced by socio-cultural phenomena, such as traditions and customs. Research suggests that the implementation of electronic prescriptions can reduce prescription errors caused by illegible handwriting, thereby improving medication safety. However, adopting this technology requires an understanding and adaptation to existing workplace cultures and healthcare habits. Key factors in the effective implementation of EMM include staff readiness to accept technological changes, adequate training, and

management support. By addressing these socio-cultural aspects, EMM can be seamlessly integrated into clinical practice, ultimately improving patient safety and healthcare service quality (Torar & Wulandari, 2023).

Based on several studies, it can be concluded that the use of Electronic Medication Monitor (EMM) in telenursing is not always proven effective in enhancing TB patient treatment services. This is due to community challenges in accepting technology and ease of use. These differences in findings highlight the importance of considering the specific context and other factors that may affect the effectiveness of technological interventions. These factors include the capacity of the healthcare system, healthcare providers' attitudes toward technology, and patients' digital literacy.

CONCLUSION

The digital transformation in nursing has played a crucial role in improving the quality of healthcare services for tuberculosis (TB) patients. Various technologies, such as telehealth, telenursing, and mobile health (mHealth) applications, have proven effective in enhancing patient adherence to treatment, facilitating real-time patient condition monitoring, and providing interactive education and support. Several studies indicate that SMS- and WhatsApp-based telenursing improves patient compliance with medication, while mHealth applications assist patients in self-managing TB treatment.

Despite the numerous benefits of digital technology, several challenges remain in its implementation, including limited internet access, the readiness of healthcare professionals, and patient engagement in using digital applications. Therefore, a more comprehensive strategy is needed to ensure the sustainability of these technologies within the healthcare system. The integration of digital technology with existing healthcare services and the enhancement of digital literacy among both patients and healthcare providers are essential steps in supporting the success of TB treatment and the future elimination of the disease. Additionally, socio-cultural factors, such as traditions and community beliefs about certain treatment methods, also influence the extent to which digital technology can be effectively accepted and utilized within the healthcare system.

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