

The effectiveness of telemedicine for Glycemic (HbA1c) management of patients with Diabetes Mellitus Type 2: A meta-analysis

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ARTICLE INFO

Article history:

Submitted 17 April 2025

Accepted 27 July 2025

Published 30 July 2025

Keyword:

Degenerative disease

Diabetes mellitus

Effectiveness

HbA1C

Telemedicine

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DOI: 10.47679/makein.2025261

ABSTRACT

Diabetes mellitus (DM) is a degenerative disease caused by genetic and environmental factors. Therefore, patients with DM type 2 requires regular control. One of the health facilities that allows a fine control and follow up over patients with DM is telemedicine. This study aimed to estimate the average effectiveness of telemedicine on glycemic management (HbA1C) of patients with DM type 2. The current research employed a systematic review with meta-analysis research design. The subjects of the study were articles published in 2005 - 2021. The article search was conducted for a maximum of 1 month over journal databases: PubMed, ScienceDirect, and Google Scholar. The primary study employed Randomized Controlled Trial with articles search according to the established PICO model, where P (Population), in this sense, patients suffering from DM type 2, I (Intervention) which was Telemedicine, C (Comparison) or non-telemedicine, and O (Outcome), which was glycemic management (HbA1c). A total of 10 primary studies were assessed with Critical Appraisal Center for Evidence-Based Medicine (CEBM). The results demonstrated that telemedicine is effective in glycemic management (HbA1c) of DM type-2 patients with a p-value of <0.05, namely $p < 0.04$ and a standardized mean difference (SMD) value of -0.24 (95% CI, -0.34 to -0.15). The results of this meta-analysis provide strong scientific evidence regarding the benefits of telemedicine in lowering HbA1c levels in patients with type 2 DM.



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INTRODUCTION

Diabetes Mellitus (DM) is a degenerative disease affected by genetic or environmental factor (Mambiya et al., 2019; Dendup et al., 2018). WHO reported that the number of DM survivors increases nearly fourfold since 1980 up to 422 million, and they are deemed to reach 693 million by 2045 (Cho et al., 2018). DM has several types, one of which is DM Type 2 (Artasensi et al., 2020; Skyler et al., 2017). This type of disease is characterized by high blood sugar levels for insulin concentration deficiency and a pancreatic hormone involved in managing glycemia (Chatuphonprasert et al., 2018, Banday et al., 2020). The International Diabetes Federation (IDF) predicted that 151 million people in the world suffered from DM 2. This estimate increased to 463 million in 2019, which indicated a triple global burden during this period (Tinajero & Malik, 2021) with its prevalence rate up to 12.2%, where DM type 2 reached 90% (Zhang et al., 2022). The

increasing number of T2DM cases is directly proportional to the rising number of complications due to poor glycemic control, including cardiovascular disease, nephropathy, and retinopathy. HbA1c is considered the primary indicator for monitoring long-term blood glucose levels and treatment effectiveness in T2DM.

At the beginning of 2020, the world experienced a Covid-19 pandemic that significantly disrupted people's daily life around the world (Hampshire et al., 2021; Liu et al., 2021). To suppress its spread, each country-imposed protocols as a preventive measure against the spread of the virus, such as the use of masks, online teaching and learning activities, restrictions on business operations and some facilities (Rahman et al., 2022; Wismans et al., 2022). Meanwhile, certain treatment is required for DM type 2 (Felix H et al., 2021). One of the necessary care is the regular control to deal with DM, which is HbA1c examination (Schnell et al., 2017; Imai et al., 2021). HbA1C represents a replacement for

markers of glucose concentration in the blood 8-12 weeks before and only 50% of HbA1c values represent deep glucose exposure in the previous 30 days (Little et al., 2019; Arch et al., 2016). Meanwhile, 40% of them were exposed on 31-90 days before, and 10% on 91-120 days (Wang et al., 2021). During the pandemic, access to in-person health services was limited, which posed a challenge for T2DM patients in maintaining consistent monitoring and control of their blood glucose levels.

Poorly controlled DM will significantly be vulnerable to Sars-Cov-2 (Li et al., 2021). Adults with uncontrolled DM type 2 and hospitalized for COVID-19 are more likely to demand for ventilators (Yan et al., 2020), to stay longer in the hospital, and to have a higher mortality rate with controlled DM type 2 (Felix H et al., 2021, Assaad et al., 2022). Several solutions have been offered to maintain and control DM type-2 during the pandemic, one of which is telemedicine service, which is commonly applied in the hospital (Sartore et al., 2023, Papazafropoulou, 2022). The implementation of telemedicine offers an alternative for continuity of care during mobility restrictions, and potentially beyond the pandemic period, especially for chronic diseases such as T2DM. Telemedicine allows for real-time consultations, continuous monitoring of glycemic control, timely feedback from healthcare providers, and improved accessibility for patients in rural or underserved areas. Systematic evidence shows that telemedicine supports individualized diabetes education, enhances treatment adherence, and leads to better health outcomes by reducing HbA1c levels significantly (AlQassab et al., 2024). Moreover, telemedicine reduces travel costs, minimizes exposure to infectious disease, and enables multidisciplinary care coordination (El-Tallawy et al., 2024).

Telemedicine is an applicable option for patients in need of medical guidance, such as consultation with a doctor (Wang et al., 2021, Kichloo et al., 2020, Nittari et al., 2022). Besides, it allows patients to connect, learn online, as well as extend self-care practice (Whitehouse et al., 2021, Lee et al., 2019). It also enables healthcare teams to offer and provide solutions for patient (Zhang et al., 2022). Many countries have identified primary telemedicine as one of the important strategies in improving access to health services for patients with chronic diseases (Gao et al., 2022). The use of telemedicine has a high level of satisfaction for users, especially patients who cannot meet face-to-face ($r=0.948$; $P<.001$). Based on study conducted by Mishra et al. (2021), providing telemedicine education by instructors increases patient satisfaction, and 77% of patients can follow instructions for using insulin correctly. In addition, Eberle et al. (2021) study states that telemedicine-using applications can improve glycemic control by significantly reducing HbA1c values in T1DM and T2DM patients. There is a positive effect of increasing self-efficacy and self-care for T2DM patients who use telemedicine compared to usual care (-0.54% , 95% CI -0.8 to -0.28). These findings are in line with the principles of self-management theory and the Chronic Care Model, which emphasize patient empowerment, goal setting, and proactive follow-up areas in which telemedicine plays a vital role.

The implementation of telemedicine in the management of type 2 DM has been shown to provide significant benefits in improving patient glycemic control (Getie et al., 2025). Study by Casas et al. (2023) show that routine monitoring through telemedicine allows for early detection of changes in blood glucose levels, allowing medical intervention to be carried out more quickly (Casas et al., 2023). In addition, this service provides wider access for patients who live in remote

areas or have limited mobility, who previously had difficulty accessing health facilities directly. Thus, telemedicine is an effective solution in maintaining the sustainability of care for type 2 DM patients, especially in the midst of the challenges posed by the COVID-19 pandemic (Chiaranai et al., 2024).

In addition to the benefits in glycemic monitoring, telemedicine also contributes to increased patient compliance in following therapies and medical recommendations (Mannoubi et al., 2024). Through a more flexible online consultation, patients can communicate with medical personnel without having to face time and distance constraints. This more intensive interaction allows for more effective health education, so that patients better understand the importance of a healthy diet, physical activity, and the use of prescribed medications. With the increase in adherence to therapy, it is hoped that the number of complications due to type 2 DM can be minimized in the long term (Almalki et al., 2024).

The sustainability and development of telemedicine services in the management of type 2 DM requires support from various parties, including medical personnel, the government, and health technology service providers (Yeung et al., 2023). Clear regulations and adequate digital infrastructure are key factors in the successful implementation of telemedicine at large. In addition, more research is needed to evaluate the long-term effectiveness of these services as well as their impact on patients' quality of life. With continuous innovation in health technology, telemedicine has the potential to become a key strategy in improving the management of type 2 diabetes in the future (Ezeamii et al., 2024). Given the high incidence of type 2 diabetes and its impact on public health, research on the effectiveness of telemedicine in improving glycemic control is essential. This study, therefore, analyzes the effectiveness of telemedicine in glycemic (HbA1C) management.

However, previous studies examining the effect of telemedicine on HbA1c in T2DM patients have produced inconsistent results. Some reported significant improvements, while others found only modest effect. Many of these studies also have limitations, such as small sample sizes, short intervention durations, or lack of subgroup analysis by type of telemedicine platform. Therefore, a meta-analysis is required to synthesize existing evidence and determine the overall effectiveness of telemedicine in improving glycemic control. This study aims to analyze the effectiveness of telemedicine in glycemic (HbA1c) management among patients with T2DM, by addressing the heterogeneity of previous findings and highlighting its relevance in the context of chronic disease care supported by digital health innovations. Therefore, this meta-analysis including only randomized controlled trials (RCTs) to ensure the highest level of evidence. This study highlighting the current applicability of telemedicine in chronic disease management. This provides a novel contribution to the existing literature by offering more robust and time-relevant evidence for clinical practice and health policy.

METHOD

Research Design

This study is a systematic review and meta-analysis. It employs secondary data from the previous research. Primary studies used are research articles conducted from 2005 to 2021 (The year 2005 marked the first phase of significant

developments in the use of information and communication technology in healthcare, including the early implementation of telemedicine systems. The articles analyzed until 2021 are the year of the pandemic which in this range is important because it encourages an increase in the use of telemedicine globally) (Eniojukan, 2024).

Research Setting

The article search was conducted through three journal databases: PubMed, ScienceDirect, and Google Scholar. The search strategy used combinations of keywords and Boolean operators as follows "telemedicine" OR "m-Health" OR "e-Health" AND "diabetes mellitus type 2" AND "glycemic control" OR "HbA1c" AND "randomized controlled trial" OR "RCT". The final search was completed on May 15, 2025.

The screening process in this study was carried out in four distinct stages to ensure the inclusion of relevant and high-quality studies. First, duplicate articles were identified and removed using the Mendeley reference manager to avoid redundancy in the review. Following this, a preliminary screening of titles and abstracts was performed based on the predefined eligibility criteria to identify potentially relevant studies. In the third stage, full-text articles of all shortlisted studies were thoroughly assessed to determine their suitability for inclusion. Finally, the selected studies underwent a critical appraisal conducted independently by multiple reviewers to ensure objectivity and methodological rigor in the final selection.

Inclusion and Exclusion Criteria

The screening process was conducted in four systematic stages to ensure the selection of relevant and high-quality studies. First, the eligibility criteria were established using the PICOS framework, which includes Population, Intervention, Comparison, Outcome, and Study Design as the basis for determining study inclusion and exclusion. The inclusion criteria consisted of full-text articles published in English between 2005 and 2021 with a randomized controlled trial (RCT) design. The studies had to involve patients diagnosed with type 2 diabetes mellitus and apply any form of telemedicine or digital health-based intervention. These were compared to conventional or non-telemedicine approaches. The primary outcome of interest was HbA1c levels.

On the other hand, studies were excluded if they were not published in English, utilized observational designs, case reports, reviews, or non-RCTs. Studies that did not report HbA1c as a measurable outcome or that had incomplete data or inaccessible full texts were also excluded. This multi-stage screening process included the removal of duplicate records using Mendeley reference manager, title and abstract screening based on the predefined eligibility criteria, full-text assessment of potentially relevant articles, and a final selection with critical appraisal conducted independently by two reviewers.

Data Collection

The current study includes full paper articles with randomized controlled trial and telemedicine for intervention. The control of this study is the treatment without telemedicine service. The subjects are patients with DM type 2, and the outcome is a decrease in HbA1C. This study excludes articles written in languages other than English and those published before 2005.

Quality Assessment

The methodological quality of the included studies was assessed using the Critical Appraisal Checklist developed by The Center for Evidence-Based Management (CEBMA). This checklist consists of 12 items designed to evaluate the internal validity, reliability, and applicability of randomized controlled trials. The criteria include clarity of research focus, adequacy of sample size, appropriateness of randomization, comparability between intervention and control groups at baseline, objectivity of outcome measurement, use of blinding, consideration of confounding factors, relevance of effect size, and generalizability of findings. Each item in the checklist was scored dichotomously as "1" (yes) if the criterion was met or "0" (no or unclear) if it was not met. A cumulative score was then calculated for each study, with a total possible score of 12. Only studies that achieved a minimum score of 9 out of 12 (75%) were included in the meta-analysis. The quality appraisal process involved two independent reviewers who assessed each article separately. Prior to the assessment, both reviewers underwent training on the use of the CEBMA tool to ensure consistency in interpretation and scoring. During the appraisal process, the reviewers were blinded to each other's assessments to minimize potential bias. After completing their independent evaluations, the reviewers compared their scores. Any discrepancies in the scoring of individual items were discussed in a consensus meeting. If consensus could not be reached, a third independent reviewer was consulted to arbitrate and provide a final decision. This adjudication process ensured that all included studies met a consistent threshold of methodological quality and that potential disagreements were resolved objectively. The results of this quality assessment formed the basis for study selection prior to data synthesis.

Process and Data Analysis

The selected articles were then assessed for the research quality. The quality research adopted Critical Appraisal CEBMA (The Center for Evidence-Based Medicine) consisting of 12 questions: 1) if the study addresses a distinct research focus; 2) if the randomized controlled trial is relevant to answer the research questions; 3) if there are enough subjects to claim that the findings are not a coincidence; 4) whether the subjects are allocated into the experimental group and the control group randomly; or else, if it can lead to bias; 5) whether it employs inclusion and exclusion; 6) if the two groups are similar when they start learning; 7) if the outcome criteria are unbiased; 8) if the measurement method is validated to examine the results; or else, if the result is assessed by an individual who did not know the group task (i.e., whether it is made by blind assessment); 9) whether the effect size measure is practically relevant; 10) how accurate the estimated effect is; if there is a confidence interval; 11) if there are confounding factors that have not yet been considered; and 12) if the results are applicable to your research. Then, an assessment is given for each question with 1 (which means 'yes') and 0 (which means 'no') and not explained. The critical appraisal process was cross-shared between the researcher and two independent people to get valid results. Articles selected are those that have a score of > 75% of 100%.

Data processing was made with the Review Manager (RevMan 5.3) by calculating standardized mean difference to figure out the combined research models and form the results of the meta-analysis. The results in this study

produce forest plot and funnel plot. Forest plot presents the information of each study and estimates of overall results under meta-analysis. Funnel plot is a diagram in a meta-analysis used to demonstrate possible publication bias. Funnel plot visualizes the magnitude of variation (heterogeneity). It also shows the relationship between effect size and the sample size in various studies.

Table 1. The Critical Appraisal of Telemedicine Effectiveness for Glycemic Management (HbA1C) of Patients with Diabetes Mellitus Type 2

Author name and Publication year	List of Questions												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Amante et al., 2021	1	1	1	1	1	0	1	1	1	1	0	1	10
Anderson et al., 2010	1	1	1	1	1	0	1	1	1	0	1	1	10
Odnoletkova et al., 2016	1	1	1	1	1	1	1	1	1	1	0	1	10
Bujnowska-Fedak et al., 2011	1	1	0	1	1	1	1	1	1	1	0	1	10
Fortmann et al., 2017	1	1	1	1	1	1	1	1	1	1	0	1	11
Stone et al., 2010	1	1	1	1	1	1	1	1	1	1	0	1	11
Greenwood et al., 2015	1	1	0	1	1	1	1	1	1	1	0	1	10
Quinn et al., 2011	1	1	1	1	1	0	1	1	1	1	0	1	10
Iljaz et al., 2017	1	1	1	1	1	0	1	1	1	1	0	1	10
Vinitha et al., 2019	1	1	1	1	1	0	1	1	1	1	1	1	11

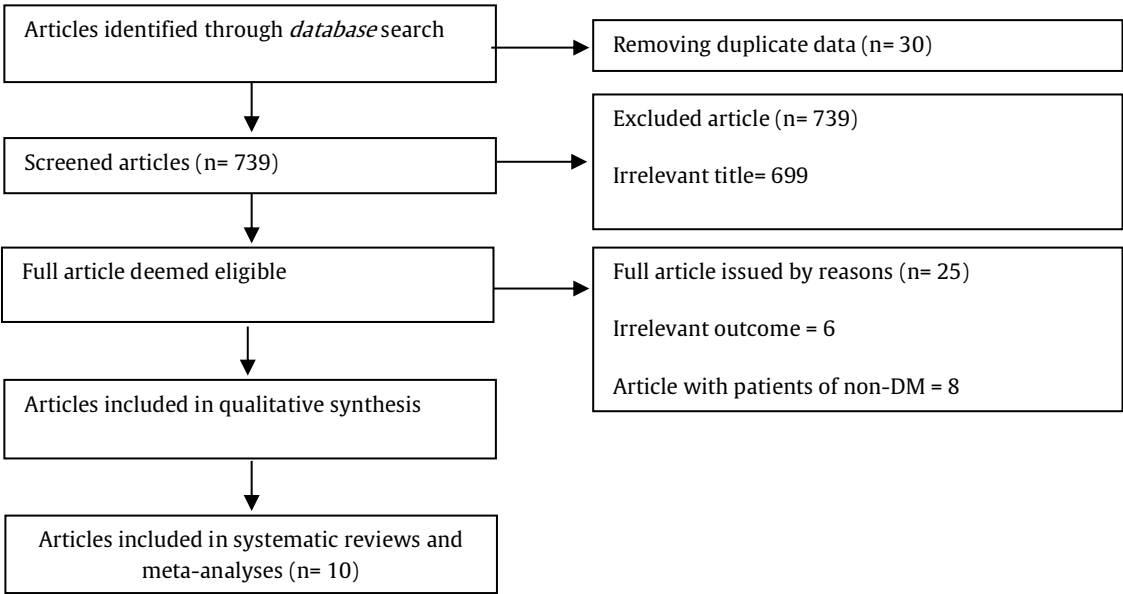


Figure 1. Prisma Flowchart

RESULTS OF STUDY

Population Characteristics

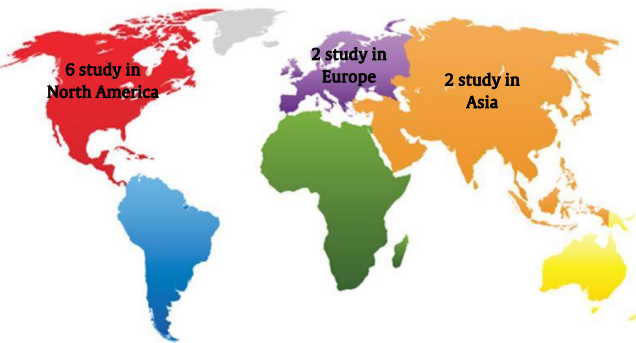


Figure 2. Map of Study on Telemedicine Effectiveness in Glycemic (HbA1C) Management of Patients with Diabetes Mellitus Type-2

The article search was made in the journal databases: PubMed, ScienceDirect, and Google Scholar. The used keywords were “telemedicine” AND “diabetes mellitus type 2” OR “glycemic management” AND “randomized controlled trial ”. The review process of related articles using PRISMA Flow Diagram is as in Figure 1. Further, it consists of 10 articles from 3 continents: America, Asia, and Europe. There were ten randomized controlled trial research articles as the source of the meta-analysis The Effectiveness of Telemedicine for Glycemic (HbA1C) Management of Patients with Diabetes Mellitus Type 2. The population in this study were patients with T2DM. The sample range in this study ranged from 42 to 517 samples divided into control and intervention groups. The result of the intervention carried out in the primary analysis was a decrease in HbA1c levels after the intervention for six months.

Table 2. Methodological Characteristics of the Studies

Study	Country	Utilization		Gender distribution (Male/female)	
		Telemedicine	Non telemedicine	Control	Intervention
Amante et al., 2021	United States	56	60	58/NA	48/NA
Anderson et al., 2010	United States	146	149	43/57	41/59
Odnoletkova et al., 2016	Belgium	252	265	63/37	60/40
Bujnowska-Fedak et al., 2011	Polandia	47	48	52/48	55/45
Fortmann et al., 2017	United States	63	63	24/76	27/73
Stone et al., 2010	United States	64	73	NA	NA
Greenwood et al., 2015	United States	45	45	NA/47	NA/55
Quinn et al., 2011	United States	27	15	50/50	52/48
Iljaz et al., 2017	Slovenia	58	62	60/40	62/38
Vinitha et al., 2019	India	112	106	67/33	68/32

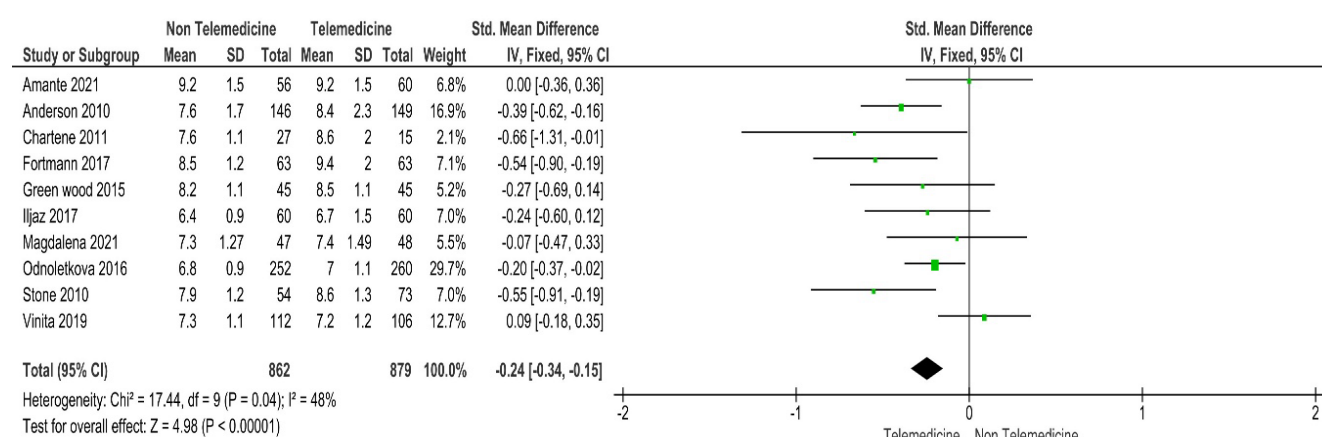
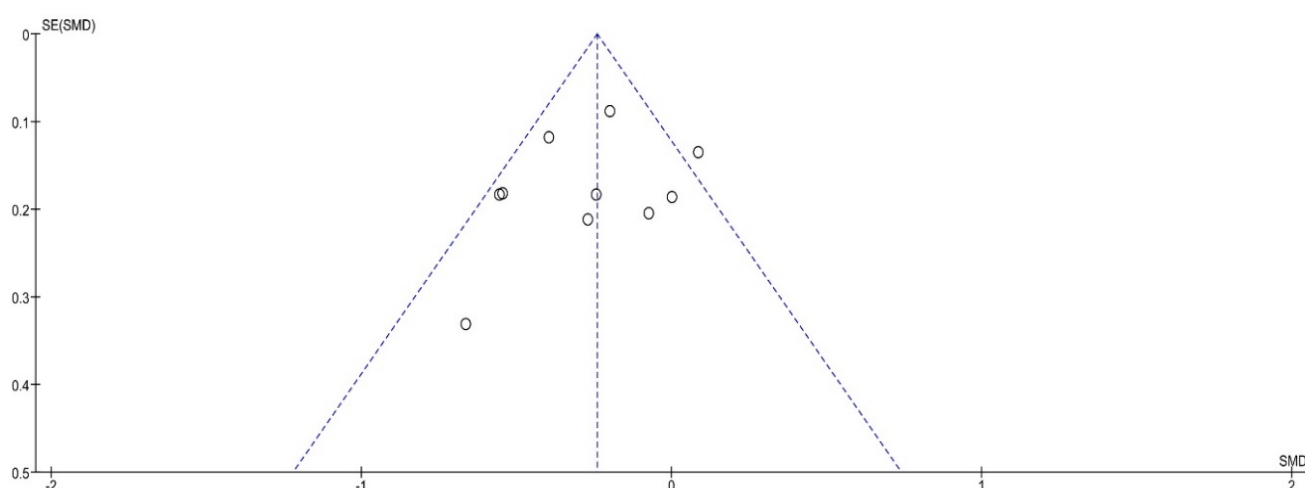
**Figure 3.** The Forest Plot of Telemedicine Effectiveness in the Management of Glycemic (HbA1C) in Patients with Diabetes Mellitus Type-2**Figure 2.** The Funnel Plot of Telemedicine Effectiveness in the Management of Glycemic (HbA1C) in Patients with Diabetes Mellitus Type-2

Table 3 (APPENDIX) presents a total of 11 randomized controlled trials (RCTs) included in this meta-analysis, with participant samples ranging from 42 to 517 individuals per study. The mean participant age varied between 39 and 58 years, with all studies targeting adult patients diagnosed with Type 2 Diabetes Mellitus (T2DM). The telemedicine

interventions utilized across studies include a wide range of modalities such as mobile phone SMS coaching, tablet or laptop-based glucose monitoring, nurse-led telecoaching, electronic health record (EHR)-coordinated phone services, and web-based self-management platforms. All interventions were compared against standard or routine

care delivered in traditional clinical settings. In terms of geographical distribution, most studies were conducted in the United States (6 studies), followed by Europe (Belgium and Poland), Asia (India and Turkey),

Based on the forest plot, the meta-analysis shows that telemedicine interventions are effective in reducing HbA1c levels among patients with type 2 diabetes mellitus. The standardized mean difference (SMD) is -0.24, with a 95% confidence interval (CI) ranging from -0.34 to -0.15, and a p -value < 0.001 . Based on Cohen's guidelines, SMD values of -0.2 to -0.5 are categorized as minor to moderate effects, but remain clinically relevant, especially in the context of chronic disease management such as diabetes. In a clinical context, a decrease of 0.2–0.3% in HbA1c was associated with a reduced risk of microvascular and macrovascular complications, including retinopathy, nephropathy, and cardiovascular disease. At a population scale, the widespread implementation of telemedicine services can have a significant aggregate impact on glycemic control and health system load, especially in areas with limited access to direct services. These findings indicate a statistically significant improvement in glycemic control among patients receiving telemedicine interventions compared to those receiving usual care. The heterogeneity test revealed a moderate level of heterogeneity, with an I^2 value of 48%, suggesting that approximately half of the variation across studies is due to differences in effect sizes rather than chance. The Cochran's Q test also supported the presence of heterogeneity ($p < 0.001$). Therefore, the findings from this meta-analysis support the conclusion that telemedicine contributes to a modest but meaningful reduction in HbA1c levels in individuals with type 2 diabetes mellitus.

The funnel plot in Figure 4 displays the relationship between the standard error (SE) of the standardized mean difference (SMD) and the effect sizes from the included studies. The plot demonstrates a roughly symmetrical, inverted funnel shape, with the studies distributed fairly evenly on both sides of the vertical line representing the overall effect size. This symmetry indicates a low likelihood of publication bias, suggesting that smaller studies with both positive and negative results were equally likely to be published and included in the meta-analysis. Moreover, none of the studies fall far outside the pseudo 95% confidence limits, further supporting the absence of significant small-study effects or selective reporting. Given that the number of studies included is relatively small ($n=10$), a visual inspection of the funnel plot is considered an appropriate method to assess potential publication bias. However, as previously mentioned, statistical tests such as Egger's regression were not performed due to insufficient power when fewer than 10 studies are analyzed. In conclusion, the visual symmetry of the funnel plot provides no strong evidence of publication bias affecting the observed effect of telemedicine on glycemic (HbA1c) management in patients with type 2 diabetes.

DISCUSSION

This systematic review and meta-analysis discuss about telemedicine in glycemic (HbA1C) management of patients with DM type 2. The dependent variable analyzed is glycemic management, especially HbA1C in patients with DM type 2. It employs research that controls the confounding factor from the inclusion criteria, using randomized controlled trial, and the statistical results of each

study include standardized mean difference. The results of the systematic reviews and meta-analyses are presented in forest plot dan funnel plot. Forest plot presents the information of each study and estimates of overall results under meta-analysis (Murti, 2018). Funnel plot is a diagram in a meta-analysis used to demonstrate possible publication bias. Funnel plot visualizes the magnitude of variation (heterogeneity). It also shows the relationship between effect size and the sample size in various studies (Murti, 2018).

Based on the results of forest plot, this study found that patients with diabetes type 2, who receive intervention through telemedicine experience a decrease in HbA1c levels by -0.24 times compared to those who do not receive intervention by telemedicine (SMD=-0.24); CI 95% -0.34 to -1.5; $p=0.004$). Based on the results of forest plot, this study found that patients with diabetes type 2, who receive intervention through telemedicine experience a decrease in HbA1c levels by -0.24 times compared to those who do not receive intervention by telemedicine (SMD = -0.24; 95% CI: -0.34 to -0.15; $p = 0.004$; $I^2 = 48\%$). This finding, although statistically modest, holds important clinical meaning. Previous studies have shown that a reduction in HbA1c as small as 0.2–0.3% can significantly reduce the risk of microvascular complications, such as retinopathy and nephropathy. This is in line with the finding of the research by Zhang et al. (2022) that telemedicine intervention for 6 months resulted in a significant reduction in HbA1c levels with an average decrease from 0.1% to 0.32%. The concentration of HbA1C effectively reflects the average blood glucose of the patient 8–12 weeks before (Zhang et al., 2022). According to research by Hanlon et al. (2017) the whole evidence of telehealth or telemedicine indicated that self-management interventions for DM type 2 show evidence of effective glycemic control. Compared to previous meta-analyses, the results of this study show a slightly smaller effect size. For instance, Wu et al. (2018) reported an SMD of -0.37. This difference may be attributed to variations in study design, duration of intervention, telemedicine platforms used, and participant engagement levels. In contrast, our meta-analysis strictly included randomized controlled trials, which typically yield more conservative effect estimates (Wu et al., 2018).

Telemedicine, which is the delivery of clinical services remotely using information and communication technology, is increasingly recognized and in demand since the outbreak of the Covid-19 outbreak (Lin et al., 2020). The use of digital technology needs to be encouraged for integrated chronic disease management services in order to create continuity because to control diabetes, it is not enough to just come once, be treated and then recover (Rhee et al., 2020). Treatment must be continuous and monitored by a doctor (Aberer et al., 2021; Zhang, 2021). The benefits are enormous if digital technology in chronic disease management services is carried out properly. Various indications suggest that interest in telemedicine will persist after the Covid-19 pandemic (de Kreutzenberg, 2022; Benis et al., 2021). Telemedicine can help the target to achieve universal healthcare coverage (Wilson et al., 2021; Jin et al., 2020). This technology can be a solution to limited health infrastructure and human resources which is the cause of limited access to health services for the community (Kim & Zuckerman, 2019).

Intervention by telemedicine promotes better self-management and reduces complications in patients with DM type 2. Treatment by telemedicine is designed for patients with DM type 2 to get information about blood glucose

monitoring, diet, exercise, and to provide them with personalized message reminders on time based on the data already obtained (Zhang et al., 2022). This corresponds to the research conducted by de Kreutzenberg (2022) which reveals that the use of telemedicine is highly possible to do if the doctor and the patient are at a considerable distance. Therefore, telemedicine is the right choice to ensure that patient education remains planned, controlling the patient's diet and suggested physical activity. Telemedicine is one way for patients who need direct contact with specialists despite limited distance, time and opportunity during a pandemic. Telemedicine also helps many doctors and facilitators in helping to supervise patients with their limitations. In addition to improving education and access, telemedicine contributes to better therapy adherence through interactive platforms that enable patients to receive regular feedback, motivational prompts, and real-time communication with healthcare providers.

From a theoretical perspective, the success of telemedicine interventions can be explained through the Chronic Care Model (CCM), which emphasizes proactive, patient-centered approaches supported by health systems and community resources (Samal et al., 2021). Telemedicine aligns well with this framework by enabling continuous monitoring, decision support, and patient self-management, critical components for managing chronic conditions like diabetes. Additionally, the Technology Acceptance Model (TAM) underlines the importance of perceived ease of use and usefulness, both of which influence patients' and clinicians' willingness to adopt digital health platforms (Lee et al., 2025).

In terms of service development, telemedicine presents significant opportunities. Health systems can integrate telemedicine platforms with electronic medical records (EMRs) for real-time decision support and patient tracking. Training healthcare workers to deliver digital care, investing in robust ICT infrastructure, and creating policies that ensure reimbursement and patient data protection will be vital. Tailored solutions are also needed to address disparities in digital access, especially in rural or low-resource settings. These developments would enable scalable, cost-effective, and equitable chronic disease management beyond the pandemic context (Gardner et al., 2025).

From a health policy perspective, telemedicine is expected to be a strategic component in efforts to achieve Universal Health Coverage (UHC), especially with its ability to reach populations living in remote areas or with limited mobility (Ojo et al., 2021). In the global context, telemedicine is also in line with the digital transformation agenda driven by WHO and various international institutions to improve the efficiency and equitable distribution of health services. At the national level, the integration of telemedicine in primary care systems has the potential to strengthen chronic disease management, accelerate responses to the growing burden of disease, and reduce access gaps between regions. However, despite its great potential, the implementation of telemedicine faces a number of significant challenges. Among them are technological infrastructure gaps, especially in disadvantaged areas; low digital literacy among patients and health workers; concerns about data privacy and security; and the lack of uniform financing policies and regulations in various countries. Therefore, the success of telemedicine on a broad scale requires strong policy support, investment in digital infrastructure, and ongoing training for health workers. Synchronization between national regulations and global standards is also key to ensuring the

quality of service and the protection of patients' rights in the use of this technology (Tenkorang et al., 2025).

Despite the positive findings, this study has several limitations. First, there was variation in the type of telemedicine interventions used (e.g., SMS, mobile apps, telecoaching), which may have influenced the effect size. Second, the majority of included studies had relatively short follow-up durations (3 to 6 months), making it difficult to assess the long-term sustainability of the interventions. Third, possible selection bias may exist, since participants who volunteer for telemedicine studies tend to have higher digital literacy and motivation levels. For future research, it is recommended to conduct longer-term studies, evaluate cost-effectiveness, and perform subgroup analyses to identify the most effective telemedicine platforms. Furthermore, integrating telemedicine into real-world healthcare systems will require addressing challenges such as clinician workload, digital infrastructure, and patient access equity.

CONCLUSIONS AND RECOMMENDATION

Telemedicine can positively be integrated in the effective management of diabetes mellitus during the Covid-19 pandemic. It is highly effective for glycemic management (HbA1c) of DM type-2 patients, thus recommendable for use by health professionals as an alternative to the administration of vital services in the management of diabetes mellitus. It provides better self-management and reduces complications upon the process of treatment. In addition to its clinical benefit, the observed reduction in HbA1c levels, although modest (SMD = -0.24), this effect size is clinically meaningful, representing improved metabolic control that can significantly reduce the risk of long-term complications. Given the growing burden of chronic disease and persistent disparities in healthcare access, particularly in remote or underserved areas, the urgency of integrating telemedicine into routine primary healthcare is clear. Telemedicine supports better self-management, facilitates timely communication with healthcare providers, and improves adherence to therapy, a critical component of diabetes management. These findings underscore the policy relevance of telemedicine as a scalable and sustainable strategy for chronic disease management, especially in populations with limited access to in-person care. Integrating telemedicine into national health systems could strengthen continuity of care, support patient education, and improve treatment adherence. Therefore, telemedicine should be considered not only as an emergency solution during the pandemic, but also as a long-term component of diabetes care delivery. Regarding to this, the author provide suggestion for this study that telemedicine can be systematically connected to ERM (Electronic Record Management) in the future. Future studies are recommended to further explore the impact of telemedicine not only on glycemic control, but also on patients' quality of life, long-term adherence to treatment, and other clinical outcomes.

DECLARATION

Ethics approval and consent to participate

Not applicable

Consent for publication

As this study is a meta-analysis, no direct involvement of human participants was required.

Availability of Data and Material (ADM)

All data analyzed during this meta-analysis were obtained from previously published studies. Additional information is available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no conflict of interest.

Funding

This study was conducted using the authors' own resources.

Artificial Intelligence-Assisted Technology

The authors declare that no generative artificial intelligence (AI) tools were used in the writing or editing of this manuscript.

Authors' contributions

This study was conceived and designed by SIP, NDS, and ASF. SIP and ASF conducted the initial literature search and data extraction. NDS and PSA were responsible for data screening, quality assessment, and data synthesis. Statistical analysis and interpretation were performed by SIP and PSA. The manuscript was drafted by SIP and ASF. Critical revision and final approval of the manuscript were done by ASF and PSA. All authors have read and approved the final version of the manuscript.

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APPENDIX**Table 3.**

Description of the Study on the Effectiveness of Telemedicine for Glycemic (HbA1C) Management of Patients with Diabetes Mellitus Type-2

Author (Year)	Country	Study Design	Sample	Age (Mean $\pm$ SD)	Variation of telemedicine	Population	Intervention	Comparison	Outcome
Amante et al. (2021).	United States	Randomized Controlled Trial.	Telemedicine: 56 Non-Telemedicine: 60	18-65 (56.7 $\pm$ 11.6)	Cellular-connected glucose meter and phone/SMS coaching by Certified Diabetes Educators	Sufferer of DM type 2.	To examine the effects of a 6-month diabetes remote monitoring program facilitated by a cellular-connected glucose meter (telemedicine) to the recording of blood glucose in adults with uncontrolled T2D.	To see the effects of blood glucose in adults with uncontrolled T2D without inclusion in the intervention group of telemedicine.	HbA1c for 6 months.
Anderson et al. (2010).	United States	Randomized Controlled Trial.	Telemedicine: 146 Non-Telemedicine: 149	≥ 18 (no mean provided)	EHR-coordinated call center	Sufferer of DM type 2.	To test the effectiveness of the disease management program through additional telephone (telemedicine) compared to the conventional care for diabetic patients treated at Community Health Centers.	To examine the effects of blood glucose in adults with uncontrolled T2D in the intervention group of non-telemedicine.	HbA1c for 6 months.
Odnoletkova et al (2016)	Belgium	Randomized Controlled Trial.	Telemedicine: 252 Non-Telemedicine: 265	≥ 18 (mean SD not stated)	Nurse-led telecoaching	Sufferer of DM type 2.	To study the effects of tele-coaching interventions in influencing hba1 levels and other modifiable risk factors in people with diabetes type 2.	To study the effects of regular treatments in influencing hba1 levels and other modifiable risk factors in people with diabetes type 2.	HbA1c for 6 months.
Bujnowska-Fedak et al (2011)	Poland	Randomized Controlled Trial.	Telemedicine: 47 Non-Telemedicine: 48	18-60 (39 $\pm$ 12.1)	In-home wireless glucose monitors and data transmission	Sufferer of DM type 2.	To see the effectiveness of tele-home treatments in providing effective and affordable care for diabetic patients.	To see at the effectiveness of standard treatments in influencing glucose CADR in diabetics.	HbA1c for 6 months.
Fortmann et al (2017)	San Diego	Randomized Controlled Trial.	Telemedicine: 63 Non-Telemedicine: 63	18-75 (48.4 $\pm$ 9.8)	Digital Short Message Service-Based Intervention	Sufferer of DM type 2.	To examine mHealth'S SMS-based interventions in improving glycemic control with Diabetes type 2	To see usual care interventions (Non telemedicine) in glycemic control with diabetes type 2	HbA1c for 6 months.
Stone et al (2010)	United states	Randomized Controlled Trial	Telemedicine: 64 Non-Telemedicine: 73	Adults < 80 years (mean not reported)	Home telemonitoring (BG, BP, weight via Viterion device)	Sufferer of DM type 2.	To compare the efficacy of home telemonitoring followed with active medication management by a nurse practitioner on glycemic control with diabetes type 2.	Looked at the effect of regular monthly care on glycemic control with diabetes type 2.	HbA1c for 6 months.

Greenwood et al (2015)	United states	Randomized Controlled Trial	Telemedicine: 45 Non-Telemedicine: 45	18-65 (58 ± 11)	Tablet/Laptop-based paired glucose monitoring	Sufferer of DM type 2.	To evaluate remote monitoring interventions telehealth using glucose testing in adults with diabetes type 2.	To evaluate usual care on glucose testing in adults with diabetes type 2.	HbA1c for 6 months.
Quinn et al (2011)	United states	Randomized Controlled Trial	Telemedicine: 27 Non-Telemedicine: 15	18-64 (41 ± 11.5)	Mobile phone coaching and patient-provider web portal	Sufferer of DM type 2.	To test the effectiveness of the mobile app and web portal of patient/provider to community primary care compared to standard diabetes management in reducing glycated hemoglobin levels in patients with diabetes type 2	To test the effectiveness of standard diabetes management of patients with diabetes type 2.	HbA1c for 6 months.
Iljaz et al (2017)	Turkey	Randomized Controlled Trial	Telemedicine: 60 Non-Telemedicine: 60	18-75 (46.5 ± 14)	Web-based eDiabetes monitoring and nurse-led e-care coordination	Sufferer of DM type 2.	To test the effectiveness of Telemonitoring and web-based interventions for the management of diabetes mellitus (DM) patients	To examine the general management care for the management of diabetes mellitus (DM) patients	HbA1c for 6 months.
Vinitha et al (2019)	India	Randomized Controlled Trial	Telemedicine: 112 Non-Telemedicine: 106	20-60 (43.3 ± 8.7)	Customized Short Message Service	Sufferer of DM type 2.	To test the effectiveness of cell phone text messages in improving glycemic control in people with diabetes type 2.	To test the effectiveness of standard DM services on glycemic control of patients with diabetes type 2.	HbA1c for 6 months.