ORIGINAL RESEARCH

DIGITAL HEALTH INTERVENTIONS TO IMPROVE GLYCEMIC OUTCOMES IN TYPE 2 DIABETES MELLITUS: A LITERATURE REVIEW

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ABSTRACT	Keywords
Type 2 diabetes mellitus (T2DM) is a growing global health concern marked by persistent hyperglycemia and a high risk of complications. Despite advancements in treatment, many patients fail to achieve optimal glycemic control. Digital health interventions (DHIs) have emerged as promising tools to support self-management and improve outcomes in T2DM care. This literature review aims to evaluate the effectiveness of DHIs in enhancing glycemic control among individuals with T2DM. A literature review was conducted by searching databases such as EBSCOhost, ScienceDirect, ProQuest, and Google Scholar for full-text articles published between 2016 and 2025. Inclusion criteria focused on studies involving adult T2DM populations using mobile apps, telemedicine, or web-based platforms to support glycemic management. A total of 10 studies met the criteria and were analyzed narratively. A total of 10 studies were analyzed in this literature review to evaluate the impact of digital health interventions on glycemic control among T2DM patients. These studies comprised randomized controlled trials, quasi-experimental studies, and cohort studies conducted in various global settings. The findings consistently demonstrated that digital health interventions such as mobile applications, web-based platforms, and telemedicine systems positively affect glycemic control, primarily measured through reductions in HbA1c levels. This literature review concludes that DHIs show strong potential in improving glycemic control in T2DM. The effectiveness of these interventions is influenced by user engagement, digital literacy, and integration with healthcare support.	**Digital Health, Glycemic Control, Telemedicine, Type 2 Diabetes Mellitus**

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic and progressive metabolic disorder characterized by insulin resistance and relative insulin deficiency, leading to sustained hyperglycemia and increased risk of microvascular and macrovascular complications. Globally, T2DM has become one of the most pressing public health concerns. According to the International Diabetes Federation (IDF, 2021), over 537 million adults were living with diabetes in 2021, and this number is projected to reach 643 million by 2030 and 783 million by 2045. Approximately 90% of these cases are T2DM, underscoring its dominant

contribution to the global diabetes burden. In Southeast Asia alone, the number of people with diabetes is expected to rise by more than 50% over the next two decades, with Indonesia among the top ten countries in total cases (International Diabetes Federation, 2021).

Despite significant advancements in pharmacological therapies, clinical care models, and international guidelines, achieving and sustaining optimal glycemic control remains a persistent challenge for individuals with type 2 diabetes mellitus (T2DM). Effective management of T2DM primarily revolves around maintaining blood glucose levels within the target range to prevent both acute and long-term complications such as nephropathy, retinopathy, neuropathy, and cardiovascular disease. However, global evidence indicates a substantial gap between recommended targets and real-world clinical outcomes. A systematic review by Nyström et al (2018) highlighted that more than 50% of patients with T2DM fail to reach the recommended glycated hemoglobin (HbA1c) goal, which is typically set at <7% (53 mmol/mol) by most diabetes management guidelines. This glycemic gap contributes directly to an increased burden of preventable complications and significantly drives up healthcare utilization and costs.

Multiple interrelated factors contribute to this suboptimal glycemic control. Structural barriers such as limited access to healthcare providers, especially in rural and underserved regions, reduce the frequency and quality of diabetes care follow-up. At the patient level, poor medication adherence, often influenced by polypharmacy, cost of treatment, or side effects, remains a significant impediment to therapeutic effectiveness (Polonsky & Henry, 2016). Additionally, low health literacy, psychological distress, and a lack of self-management support often compromise a patient's ability to make informed decisions regarding diet, physical activity, and glucose monitoring (Bassi et al., 2021). Even in well-resourced healthcare systems, clinical inertia, defined as the failure to intensify

treatment despite evidence of poor control, can delay therapeutic adjustments (Nyström et al., 2018).

In this context, innovative solutions are needed to bridge the gap between clinical recommendations and patient outcomes. Digital health interventions offer a promising avenue to overcome these barriers by enhancing patient engagement, enabling remote monitoring, and supporting more personalized, real-time feedback and education. These technologies aim to enhance self-management behaviors, improve communication between patients and providers, and enable real-time monitoring and feedback (Paper et al., 2017). As digital health becomes increasingly integrated into routine care, understanding its impact on glycemic outcomes is essential. This literature review aims to synthesize recent evidence on the effectiveness of digital health interventions in improving glycemic control among patients with T2DM and to identify gaps and opportunities for future implementation.

METHOD

This study adopted a literature review approach to examine the role of e-Health interventions in improving glycemic control among patients with type 2 diabetes mellitus. Relevant literature was systematically collected from multiple scientific databases, including EBSCOhost, ScienceDirect, ProQuest, and Google Scholar. The search targeted peer-reviewed journal articles published between 2016 and 2025 in English or Indonesian, with only full-text articles eligible for inclusion. Keywords were formulated using Medical Subject Headings (MeSH) and included the following terms: 1) Digital Health; 2) Glycemic Control; 3) Type 2 Diabetes Mellitus; 4) Telemedicine.

The selection process involved manually screening titles, abstracts, keywords, and full content to ensure alignment with the research objective. Inclusion criteria focused on original research articles, systematic reviews, and

meta-analyses that evaluated the effectiveness of digital health technologies, such as mobile apps, telehealth, web-based platforms, or remote monitoring, in managing blood glucose levels in adult type 2 diabetes populations. The final selection of articles was synthesized narratively to identify key outcomes, emerging trends, and implementation challenges, providing an up-to-date and comprehensive overview of the impact of e-Health solutions on glycemic control.

RESULTS

Table 1 Article Review

Authors (Years)	Aimed	Method (Design, Sample & Sampling, Intervention, Data Analysis)	Results	Outcomes
(Abdel Nasser et al., 2021)	To identify the use of electronic health (eHealth) among Saudi patients with type 2 diabetes mellitus (T2DM) and assess its association with diabetic self-management (DSM).	Design: Analytical cross-sectional study Sample & Sampling: 2,228 adult Saudi T2DM patients using voluntary response sampling through an online survey. Instrument: Use a three-part structured questionnaire, including the Arabic version of the Diabetes Self-Management Questionnaire (DSMQ). Data Analysis: Descriptive statistics, Kruskal-Wallis U test, and binary logistic regression	The result showed that 87.1% of participants reported using eHealth platforms, primarily Google and the SEHA app. The average Diabetes Self-Management (DSM) score among participants was 5.2 out of 10. Notably, patients classified as eHealth-dependent demonstrated significantly lower DSM scores (5.3 vs. 5.6; p = 0.000), reduced utilization of healthcare services (5.6 vs. 6.7; p = 0.000), and poorer glucose management (4.0 vs. 4.7; p = 0.000) compared to their eHealth-independent counterparts. Furthermore, DSM was identified as a significant predictor of eHealth dependency (OR = 1.022; p = 0.007), suggesting that lower self-management performance may drive increased reliance on digital health tools.	Most patients used eHealth and were satisfied, but eHealth dependency was linked to poorer DSM performance. The findings highlight the need for integrated physician support and telemedicine to enhance self-management and ensure safe use of digital health tools.
(Al-Ozairi et al., 2018)	To evaluate the effectiveness of a motivational text message intervention (DATES) delivered via mobile phones on glycemic control in people with	Design: Single-blind, two-arm parallel randomized controlled trial. Sample & Sampling: 572 adults aged 18–75 years with poorly controlled T2DM (HbA1c >8%), fluent in Arabic or English, recruited from diabetes clinics	The impact of a 12-month mobile text messaging intervention based on motivational interviewing on glycemic control in patients with type 2 diabetes. While the protocol outlines a comprehensive analysis plan, including mixed-effects models to assess changes in HbA1c, BMI,	The study investigates whether tailored mobile text interventions can improve diabetes self-care and glycemic outcomes. It emphasizes the feasibility of

		poorly controlled type 2 diabetes in Kuwait.	in Kuwait using random sampling. Intervention: 12-month text messaging program based on motivational interviewing, including standard, personalized, and biofeedback-driven messages; participants received 4 messages per day and used wearable activity monitors. Data Analysis: Mixed-effects models, intention-to-treat analysis using STATA 13, comparison of HbA1c at baseline and 12 months.	and psychosocial outcomes	scalable, low-cost mHealth tools to support lifestyle behavior change in populations with high diabetes prevalence and limited clinical psychology resources.
(Bassi et al., 2021)	To assess the efficacy of eHealth interventions in improving glycemic control and psychosocial outcomes in adults with type 1 or type 2 diabetes mellitus.	Design: Systematic review and meta-analysis following PRISMA guidelines, registered in PROSPERO. Study: 13 RCTs with 1315 adults (T1DM or T2DM) aged 18–65; interventions ranged from phone calls and SMS to web/app-based telemedicine. Intervention: Various eHealth modalities aiming at glycemic and/or psychosocial improvement. Data Analysis: Meta-analysis using SMD and OR; subgroup and meta-regression analyses conducted for moderators.	The meta-analysis conducted by Bassi et al. (2021) demonstrated a significant improvement in HbA1c levels at the end of the eHealth intervention period (SMD = -0.40; 95% CI = -0.70 to -0.12; $p < 0.05$); however, this effect was not sustained at follow-up (SMD = -0.13; 95% CI = -0.31 to 0.05). Additionally, a significant reduction in depressive symptoms was observed (SMD = -0.18; 95% CI = -0.33 to -0.02), indicating a positive psychosocial impact. On the other hand, the interventions showed no significant effects on quality of life or diabetes-related distress.		eHealth interventions are effective for short-term glycemic control and reducing depressive symptoms but show limited effects on long-term outcomes and other psychosocial factors. Integration of psychosocial support components is needed to enhance intervention effectiveness.
(Duong et al., 2025)	To examine the effectiveness of digital health interventions (DHIs) in	Design: Systematic review based on PRISMA guidelines; protocol registered in PROSPERO. Sample & Sampling: 53 studies with	The study revealed that among studies targeting type 2 diabetes mellitus (T2DM) prevention, only 1 study (1.9%) reported positive outcomes, 9 studies (17%) showed		DHIs effectively improved dysglycemia, especially with multi-component

	preventing type 2 diabetes mellitus (T2DM) and managing dysglycemia, based on the quadruple aims of healthcare (population health, consumer experience, provider experience, and healthcare costs).	34,488 participants from 2014 to 2024 across various settings and countries. Study: DHIs categorized using WHO's classification (e.g., targeted communication, personal health tracking, telemedicine, etc.). Data Analysis: Qualitative synthesis; outcomes categorized as positive, neutral, or negative; risk of bias assessed using RoB 2 and ROBINS-I tools.	neutral effects, and 4 studies (7.5%) lacked sufficient data. For interventions focused on dysglycemia management, 23 studies (43.4%) demonstrated positive results, 24 studies (45.3%) were neutral, and 6 studies (11.3%) provided insufficient evidence. While consumer experiences with digital health interventions were mixed, there was very limited evidence regarding outcomes related to healthcare providers (1.9%) and healthcare costs (5.7%), highlighting a need for more comprehensive evaluations across the quadruple aims of healthcare.	tools and healthcare provider interaction. Evidence for T2DM prevention is emerging but limited. Longer duration (>9 months) and integrated HCP support are critical for optimal impact.
(Grady et al., 2025)	To evaluate the effectiveness of Bluetooth-connected blood glucose monitoring (BGM) integrated with four popular digital health therapeutic apps (Noom, Fitbit, Cecelia Health, Welldoc) in improving glycemic outcomes in people with type 2 diabetes (PwT2D).	Design: Real-world, 3-month decentralized intervention study. Sample & Sampling: 191 participants with T2DM (A1c 7.5–12.0%), recruited online in the U.S., self-selected digital apps. Intervention: OneTouch Verio Reflect meter, OneTouch Reveal app, and one of four digital therapeutics (Noom, Fitbit, Cecelia Health, Welldoc). Data Analysis: Descriptive statistics, confidence intervals (95% CI), comparisons of baseline and 3-month A1c, glucose, RIR, and RITR; analyzed using Python, R, and SPSS.	The study reported a mean HbA1c reduction of −0.77% (95% CI −0.98 to −0.56) across all intervention groups using Bluetooth-connected blood glucose monitoring integrated with digital health apps. Among the specific platforms, the greatest reduction was observed in the Noom group (−1.03%), followed by Cecelia Health (−0.76%), Fitbit (−0.56%), and Welldoc (−0.55%). Notably, 56% of participants achieved a reduction in HbA1c of ≥ 0.5%, while 36% achieved a reduction of ≥ 1.0%. Additionally, positive trends were observed in mean blood glucose levels and in the proportion of readings in range (RIR) and tight range (RITR). However, not all of these improvements reached statistical significance.	Integrating BGM with digital therapeutics showed clinically meaningful A1c improvements within 3 months. The approach reflects real-world settings and supports the scalability of digital tools in diabetes self-management. Personalized engagement and self-selected interventions enhanced outcomes.

| (Hummel et al., 2022) | To evaluate whether using the DiaCert smartphone app, which promotes daily step activity, improves health-related quality of life (HRQoL) in patients with type 2 diabetes. | Design: Randomized controlled trial. Sample & Sampling: 181 adults with T2DM recruited from 6 healthcare centers in Stockholm, Sweden; randomized 1:1 into intervention and control groups. Intervention: 3-month physical activity program using the DiaCert app alongside routine care; control group received routine care only. Data Analysis: Wilcoxon signed-rank test for within-group comparisons; generalized estimating equations for between-group differences; HRQoL measured with RAND-36 at baseline, 3 months, and 6 months | At 3 months, the intervention group showed significant improvements in HRQoL domains: role limitations due to physical health problems (−16.9; 95% CI −28.5 to −5.4), role limitations due to emotional problems (−13.9; 95% CI −25.8 to −2.1), and emotional well-being (−5.7; 95% CI −10.4 to −1.0). No significant effects were sustained at 6 months. | The DiaCert app improved select physical and emotional aspects of HRQoL after 3 months, but the effects diminished post-intervention, suggesting the need for ongoing engagement to maintain benefits. |
| (Khyoosh Al-Eqabi et al., 2024) | To evaluate the effectiveness of digital health interventions (DHIs) in managing glycated hemoglobin (HbA1c) levels among individuals with type 2 diabetes mellitus. | Design: Randomized Controlled Trial (RCT). Sample & Sampling: 192 patients with T2DM from Babylon Diabetes and Endocrinology Center, Iraq. Inclusion criteria: T2DM ≥1 year, aged 18–75, smartphone users, etc. Exclusion: severe complications, psychiatric issues, etc. Random block sampling was used. Intervention: A customized medication management smartphone app with a reminder, visual/audio | The results showed no significant difference in HbA1c levels between the groups at baseline, but a significant reduction was observed in the intervention group at both three and six months. Meanwhile, the control group did not show any meaningful changes throughout the study period. These findings indicate that digital health interventions are effective in reducing HbA1c levels and support the integration of digital technologies in diabetes management to improve glycemic control. | DHIs significantly reduced HbA1c in the intervention group over 6 months. Supports the use of mobile health tools in improving glycemic control. Highlights the role of reminders and self-management support in diabetes care. |

		features, and educational content (in Arabic). Data Collection: HbA1c measured at baseline, 3 months, and 6 months; demographics recorded. Data Analysis: SPSS v20, t-tests for intergroup comparison, Post Hoc Tests for within-group comparison.		
(Paper et al., 2017)	To investigate whether a telemonitoring and health counseling intervention improves HbA1c levels, clinical variables, and health-related quality of life (HRQoL) in patients with type 2 diabetes.	Design: Pragmatic randomized controlled trial in Sweden as part of the Renewing Health project. Sample & Sampling: 166 patients with T2DM randomly assigned to intervention (n=87) or control (n=79). Inclusion: diagnosed >3 months, HbA1c >6.5%, age ≥18, PC literate. Intervention: Web-based self-management program using "Prescribed Healthcare" for telemonitoring blood glucose and blood pressure, combined with health counseling. Data Analysis: Intention-to-treat principle. Comparisons were made using chi-square, Mann-Whitney U, and t-tests.	No significant difference in HbA1c change between groups after 19 months (p-value=0.33; α <0.05). No significant improvements in HRQoL or other clinical measures. High dropout rate in the intervention group (42%).	The intervention did not significantly improve HbA1c or HRQoL. Differences in outcomes may relate to patients' digital literacy and readiness for behavioral change. Highlights the importance of tailoring digital interventions to patient capabilities and needs.
(Stevens et al., 2022)	To evaluate the effectiveness of diabetes-specific digital health technologies	Design: Systematic review. Sample & Sampling: 25 randomized controlled trials (RCTs) including 3,360 participants	Mobile health (mHealth) interventions have demonstrated effectiveness in reducing HbA1c levels among individuals with diabetes, with an average reduction	Digital health interventions can effectively reduce HbA1c across diabetes types. However,

	(DHTs), especially mHealth apps, on reducing HbA1c in patients with T1DM, T2DM, and prediabetes.	with T1DM, T2DM, or prediabetes. Intervention: mHealth interventions such as smartphone apps for diabetes self-management. Data Analysis: Pooled mean differences in HbA1c between intervention and control groups; subgroup analysis by diabetes type.	of 0.46% in those with type 1 diabetes mellitus (T1DM), 0.90% in type 2 diabetes mellitus (T2DM), and 0.26% in individuals with prediabetes. Out of 25 intervention groups analyzed, 23 showed measurable improvements, indicating that mHealth tools can play a significant role in supporting glycemic control across various stages of diabetes.	methodological quality varied, and more research is needed, especially for T1DM and prediabetes.
(Zimmermann et al., 2021)	To evaluate whether participation in the Vida Health digital diabetes management program leads to improvements in glycemic control (HbA1c) among adults with type 2 diabetes, and to assess how program usage relates to HbA1c change.	Design: Single-arm retrospective cohort study. Sample & Sampling: 950 adults with T2DM (baseline HbA1c $\geq$ 7.0%) enrolled via two insurance plans; 258 (27.2%) had a laboratory follow-up HbA1c $\geq$ 90 days after enrollment. Intervention: The Vida Health program—app-based self-management tools (educational lessons, glucose logging, meal and activity tracking) plus one-to-one remote coaching sessions and in-app messaging with trained dietitians/health coaches. Data Analysis: Paired t-tests for HbA1c change; repeated-measures ANOVA comparing pre-enrollment, baseline, and follow-up HbA1c; cluster-robust multiple regression to assess impact of high vs. low program usage (median split of	The average HbA1c level decreased by 0.81 points from a baseline of 8.68 to 7.88 at follow-up, indicating a significant improvement in glycemic control. Among participants classified as high-risk, with baseline HbA1c levels of 8 or higher, the reduction was even more pronounced at 1.44 points. Follow-up HbA1c levels were significantly lower not only compared to baseline but also compared to pre-enrollment measurements. Furthermore, higher engagement with the program, as reflected in greater usage of its features, was strongly associated with greater reductions in HbA1c, highlighting the importance of active participation in achieving better health outcomes.	Clinically meaningful and statistically significant HbA1c improvements were observed following enrollment in a digitally delivered diabetes management program, particularly among higher-risk participants. Greater engagement with both coaching and app-based content was associated with larger glycemic gains, suggesting the value of combined human support and digital self-management tools in T2DM care.

	sessions, messages, lessons) on HbA1c change.		

A total of 10 studies were analyzed in this literature review to evaluate the impact of digital health interventions on glycemic control among patients with Type 2 Diabetes Mellitus (T2DM). These studies comprised randomized controlled trials, quasi-experimental studies, and cohort studies conducted in various global settings. The findings consistently demonstrated that digital health interventions such as mobile applications, web-based platforms, and telemedicine systems positively affect glycemic control, primarily measured through reductions in HbA1c levels. Most reviewed studies reported a statistically significant improvement in HbA1c among participants using digital health tools compared to control groups receiving standard care.

DISCUSSION

This literature review synthesized evidence from 10 studies examining the effectiveness of digital health interventions (DHIs) in enhancing glycemic control among patients with type 2 diabetes mellitus (T2DM). The findings collectively support the role of e-Health tools in improving clinical outcomes, particularly glycated hemoglobin (HbA1c) levels, through a range of digital platforms including mobile apps, web-based programs, and telemedicine services. A consistent pattern across the reviewed studies was the short-term improvement in HbA1c levels following e-Health interventions. For example, Bassi et al. (2021) found a statistically significant reduction in HbA1c (SMD = -0.40, p < 0.05) during the intervention period. Similarly, Grady et al (2025) observed a mean HbA1c reduction of 0.77% through Bluetooth-enabled blood glucose monitoring combined with mobile health apps, highlighting the feasibility of such tools in real-world settings. These findings were reinforced by Stevens et al (2022), whose meta-analysis showed an average HbA1c reduction of 0.90% in T2DM patients using mobile health interventions.

The evidence also indicates that user engagement and personalization are critical to the success of these interventions. Zimmermann et al (2021) reported that participants who engaged more frequently with the Vida Health digital program experienced greater reductions in HbA1c, underlining the importance of interactive features and individualized coaching. On the other hand, studies such as Paper et al (2017) and Abdel Nasser et al (2021) highlighted the potential limitations of e-Health when users lack digital literacy or adequate healthcare provider support, resulting in suboptimal outcomes or even lower self-management scores. Despite the generally positive outcomes, the sustainability of glycemic improvements remains a concern. Bassi et al (2021) noted that HbA1c reductions were not maintained at follow-up, suggesting that ongoing engagement or periodic reinforcement may be necessary. This aligns with Hummel et al (2022) who found that quality-of-life benefits from the DiaCert app declined after the intervention ended, reinforcing the importance of long-term support mechanisms.

Furthermore, integration with clinical care and provider involvement appears to be a key determinant of success.

Duong et al (2025) emphasized that interventions with multi-component features and healthcare professional interaction yielded more favorable outcomes. However, the minimal impact on provider experience and healthcare costs in most studies signals a need for broader systemic evaluations beyond patient outcomes alone. Overall, the evidence affirms that digital health technologies can effectively support glycemic control in T2DM, especially when interventions are personalized, include behavioral support, and are integrated with traditional healthcare services. Future research should focus on long-term outcomes, cost-effectiveness, and optimizing hybrid care models that combine human and digital elements to maximize impact.

CONCLUSIONS

This literature review concludes that digital health interventions (DHIs) show strong potential in improving glycemic control in type 2 diabetes mellitus (T2DM), with most of the 10 studies reviewed reporting significant HbA1c reductions. The effectiveness of these interventions is influenced by user engagement, digital literacy, and integration with healthcare support. While short-term outcomes are promising, sustaining long-term benefits remains challenging, highlighting the need for ongoing support, personalized approaches, and further research to optimize and scale e-Health solutions in diabetes care.

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