



Digital Health Interventions to Support Self-Management in Patients with Type 2 Diabetes

Yohanes Wenda¹, Maria Wanggai¹, Jonathan Kogoya¹

¹Nursing Science Study Program, STIKES Graha Edukasi Makassar, Indonesia

*Corresponding Author: Yohanes Wenda

E-mail:

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Abstract

This study examines the influence of digital health interventions on self-management among patients with Type 2 diabetes mellitus in Makassar, Indonesia. A quantitative cross-sectional design was employed involving 150 adult patients who actively used digital health technologies for diabetes management. Data were collected using standardized questionnaires measuring digital intervention usage, medication adherence, self-efficacy, and glycated hemoglobin levels. Statistical analyses included descriptive statistics, Pearson correlation, multiple regression, and independent samples t-tests. The findings revealed that digital health intervention usage significantly improved medication adherence, enhanced self-efficacy, and reduced HbA1c levels. Digital engagement was identified as the strongest predictor of glycemic control. The study's novelty lies in its integrated examination of clinical, behavioral, and psychological outcomes within the Indonesian healthcare context. These findings highlight the strategic role of digital healthcare technologies in supporting patient-centered chronic disease management and improving healthcare accessibility. The study provides important implications for healthcare institutions and policymakers in developing sustainable digital health systems for diabetes care.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) has emerged as one of the most critical global public health concerns due to its rapidly increasing prevalence and long-term clinical complications. The International Diabetes Federation estimated that more than 537 million adults were living with diabetes in 2021, with projections reaching 643 million by 2030. The disease is strongly associated with lifestyle transitions, including physical inactivity, obesity, unhealthy dietary habits, and aging populations. Beyond its epidemiological burden, T2DM generates substantial economic and healthcare pressures because patients require continuous monitoring, medication adherence, and long-term behavioral adjustments to prevent severe complications such as cardiovascular disease, nephropathy, neuropathy, and retinopathy (Kulkarni et al., 2024; Dar et al., 2023). In many developing countries, including Indonesia, healthcare systems continue to face limitations in providing sustainable and individualized diabetes management support, resulting in

inadequate glycemc control among patients (Sofyan et al., 2023; Kurnia et al., 2025; Rahadian Syah et al., 2025; Arini et al., 2022; Febriyanti et al., 2025).

Effective diabetes management depends largely on patients' ability to perform self-management behaviors consistently. Self-management encompasses blood glucose monitoring, dietary regulation, medication adherence, physical activity, and stress management (Osunde et al., 2025; Motaghi et al., 2023; Alhuseen et al., 2023). Previous studies have demonstrated that inadequate self-management remains a persistent challenge among patients with T2DM due to limited health literacy, low motivation, poor access to healthcare education, and insufficient continuity of care. Traditional face-to-face educational approaches have shown positive impacts on diabetes control; however, these interventions are frequently constrained by geographical barriers, limited healthcare personnel, and restricted consultation time. Consequently, healthcare systems increasingly require innovative and scalable approaches capable of supporting patients beyond conventional clinical settings (Firoozi & Firoozi, 2025; Kosiol et al., 2024).

The rapid development of digital health technologies has transformed the delivery of chronic disease management services. Digital health interventions (DHIs), including mobile health applications, telemedicine, telemonitoring systems, wearable devices, and web-based educational platforms, are increasingly utilized to facilitate patient-centered healthcare (Willis et al., 2022; Alruwaili et al., 2023; Ahmed et al., 2025). These technologies enable continuous monitoring, personalized feedback, remote consultation, and automated reminders that strengthen patient engagement in self-care activities. Prior studies reported that digital interventions contribute to improved medication adherence, enhanced self-efficacy, and reduced glycated hemoglobin (HbA1c) levels among patients with diabetes (Park et al., 2025; Chen & Wu, 2023; Chong et al., 2025; Rubab et al., 2025). Mobile applications, for example, allow patients to monitor glucose levels, record dietary intake, and receive real-time behavioral feedback, while telehealth systems support communication between patients and healthcare professionals without geographical limitations.

Recent empirical evidence further confirms the growing significance of DHIs in chronic disease management. Meta-analytic findings indicate that mobile-based diabetes interventions significantly improve glycemc control compared with standard care. Studies by Sharma et al. (2024) and Janjua et al. (2021) also demonstrated that telehealth and remote monitoring systems improve adherence behaviors and reduce hospitalization rates among patients with chronic illnesses. Nevertheless, the effectiveness of digital health technologies remains inconsistent across studies because outcomes are influenced by technological literacy, frequency of engagement, intervention design, accessibility, and patients' behavioral readiness (Alotaibi et al., 2025; Figueiredo et al., 2025; Patel et al., 2025). Several studies reported minimal or short-term effects, suggesting that the successful implementation of DHIs depends not only on technological availability but also on behavioral and psychological determinants.

One important factor influencing diabetes self-management is self-efficacy, defined as an individual's confidence in performing behaviors necessary to achieve desired health outcomes. Self-efficacy has been consistently recognized as a strong predictor of adherence to diabetes care routines, including medication compliance, dietary regulation, and physical activity (Hamidi et al., 2022). Digital health interventions are believed to strengthen self-efficacy by providing personalized feedback, motivational support, goal-setting mechanisms, and interactive educational content (Liu et al., 2025; Dong, 2025; Li et al., 2024). However, many previous studies primarily emphasized clinical outcomes such as HbA1c reduction while paying limited attention to the simultaneous interaction between digital engagement, self-efficacy, and medication adherence. As a result, the behavioral mechanisms

underlying the effectiveness of DHIs remain insufficiently explored, particularly within middle-income healthcare contexts.

Another critical issue concerns the unequal adoption of digital health technologies across developing regions. Limited digital infrastructure, disparities in internet accessibility, and low digital literacy continue to hinder the implementation of technology-based healthcare systems in many low- and middle-income countries. Although Indonesia has experienced rapid digital transformation in recent years, empirical evidence examining how digital interventions influence diabetes self-management among Indonesian patients remains limited. Existing studies largely focus on technological feasibility or descriptive evaluations rather than quantitatively examining the relationships between digital health usage, medication adherence, self-efficacy, and glycemic outcomes. This condition indicates a significant research gap concerning the contextual effectiveness of DHIs in supporting sustainable self-management behaviors within resource-constrained healthcare environments.

The state of the art of this study lies in its integrated examination of clinical and behavioral dimensions of diabetes self-management through digital health engagement. Unlike previous studies that predominantly focused on isolated clinical indicators, this research simultaneously analyzes the relationships among digital intervention usage, self-efficacy, medication adherence, and HbA1c levels using a quantitative framework. The novelty of this study is reflected in its emphasis on the behavioral pathways through which digital interventions contribute to glycemic control among patients with T2DM in the Indonesian healthcare context. By combining validated behavioral instruments with clinical indicators, this study provides a more comprehensive understanding of how technology-driven healthcare strategies influence chronic disease management outcomes.

Therefore, this study aims to quantitatively examine the influence of digital health interventions on self-management among patients with Type 2 diabetes in Makassar, Indonesia. Specifically, the research investigates the relationships between digital health engagement, medication adherence, self-efficacy, and glycemic control. The findings are expected to contribute theoretically to the development of digital health and self-management literature by clarifying the behavioral mechanisms underlying effective diabetes care. Practically, the study offers evidence-based insights for healthcare providers, policymakers, and healthcare institutions in designing scalable, patient-centered digital interventions capable of improving chronic disease management outcomes and strengthening healthcare accessibility in developing countries.

METHODS

Research Design

This study employed a quantitative research design using a cross-sectional approach to examine the influence of digital health interventions on self-management among patients with Type 2 diabetes mellitus (T2DM). Quantitative methods were selected because they enable systematic measurement of relationships among variables through statistical analysis and facilitate the generalization of findings across a defined population. The cross-sectional design was considered appropriate because the study aimed to evaluate the current relationships between digital health intervention usage, medication adherence, self-efficacy, and glycemic control at a single point in time. According to Chao (2023), cross-sectional quantitative studies are effective for identifying associations among measurable variables within health-related populations. The study specifically investigated whether the frequency and intensity of engagement with digital health tools significantly contributed to improved behavioral and clinical outcomes among patients with T2DM.

Research Setting and Participants

The research was conducted at two major diabetic outpatient clinics in Makassar City, Indonesia, where digital health tools had been integrated into diabetes education and patient monitoring services. These clinics were selected because they routinely utilized digital technologies such as mobile-based monitoring applications, telemonitoring systems, and web-based educational platforms to support chronic disease management.

The target population consisted of adult patients diagnosed with Type 2 diabetes for at least one year and actively enrolled in digital health support programs. A purposive sampling technique was employed to recruit participants who met predetermined inclusion criteria. Participants were required to be between 30 and 65 years old, registered users of digital health applications for a minimum of three months, and willing to participate voluntarily in the study. Patients with severe complications or cognitive impairments that could interfere with questionnaire completion were excluded from participation. The final sample consisted of 150 respondents, a number considered adequate for multiple regression and correlation analyses based on statistical power recommendations for medium-effect quantitative studies.

Data Collection Techniques

Data collection was conducted over a three-month period following ethical approval from the institutional review board. Both primary and secondary data sources were utilized. Primary data were collected through standardized questionnaires distributed directly to participants during outpatient visits. Secondary data were obtained from patients' clinical records, particularly their most recent glycated hemoglobin (HbA1c) results recorded within the previous three months.

Medication adherence was measured using the Morisky Medication Adherence Scale (MMAS-8), a validated instrument widely applied in chronic disease management research. Self-efficacy was assessed using the Diabetes Management Self-Efficacy Scale (DMSES), consisting of 20 Likert-scale items designed to evaluate patients' confidence in performing diabetes self-care activities. To assess digital health intervention usage, the researchers developed a structured questionnaire adapted from existing digital health utilization frameworks. The instrument evaluated the frequency of digital tool usage, types of accessed features, and perceived usefulness of the technologies. Prior to administration, all instruments were translated into Bahasa Indonesia and reviewed by two diabetes educators to ensure contextual appropriateness and linguistic clarity.

The descriptive characteristics of participants and digital health intervention usage are summarized in Table 1.

Table 1. Demographic Characteristics and Digital Health Intervention Usage

Category	Value
Total Participants	150
Age Range	30–65 years
Mean Age	56 years
Gender Distribution	53% Male, 47% Female
Digital Health Tools Used	Mobile Apps, Telemonitoring, Web-Based Platforms
Frequency of Usage	5–7 days per week

Validity and Reliability

To ensure instrument quality, a pilot study involving 20 participants was conducted prior to the main data collection process. These participants met the inclusion criteria but were excluded from the final sample. Construct validity was examined using Pearson product-moment correlation analysis, with all questionnaire items

demonstrating correlation coefficients above the acceptable threshold of 0.30. Reliability testing was conducted using Cronbach's alpha coefficients. The MMAS-8 produced a reliability coefficient of 0.82, the DMSES demonstrated a coefficient of 0.88, and the digital intervention usage scale yielded a coefficient of 0.85, indicating strong internal consistency across all instruments. According to Hair et al. (2019), Cronbach's alpha values above 0.70 indicate acceptable reliability for behavioral and clinical research instruments.

Data Analysis

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 26. Descriptive statistics were first applied to summarize demographic characteristics, frequencies of digital health intervention usage, and mean scores for medication adherence and self-efficacy. Inferential statistical analyses were subsequently conducted to test the research hypotheses. Pearson correlation analysis was used to identify the relationships among digital health intervention usage, medication adherence, self-efficacy, and HbA1c levels. Multiple linear regression analysis was employed to determine the predictive influence of digital health interventions on glycemic control. Additionally, an independent samples t-test was conducted to compare HbA1c levels between frequent and infrequent users of digital health tools. All statistical analyses were conducted using a significance level of $p < 0.05$ in accordance with standard quantitative research procedures in healthcare studies.

RESULTS AND DISCUSSION

This section presents the empirical findings regarding the influence of digital health interventions (DHIs) on self-management among patients with Type 2 diabetes mellitus (T2DM). The analysis is organized systematically to explain participant characteristics, patterns of digital health utilization, descriptive statistics of the principal variables, and inferential statistical findings. The results focus on the relationships between digital intervention engagement, medication adherence, self-efficacy, and glycemic control measured through HbA1c levels. In addition, regression assumption testing and effect size interpretation are included to strengthen the robustness of the statistical analysis. The findings collectively provide a comprehensive understanding of how technology-assisted healthcare contributes to chronic disease management within outpatient clinical settings in Makassar, Indonesia.

Participant Characteristics and Digital Health Utilization

A total of 150 adult patients diagnosed with Type 2 diabetes participated in this study. All respondents had utilized digital health interventions for at least three months before data collection. The demographic profile indicates that the respondents represented a middle-aged diabetic population, with ages ranging from 30 to 65 years and a mean age of 56 years. Male participants accounted for 53% of the sample, while female participants represented 47%, indicating a relatively balanced gender distribution.

Additional demographic analysis showed that 42% of participants had completed secondary education, while 38% possessed undergraduate educational backgrounds. Approximately 61% of respondents had experienced diabetes for more than five years, suggesting that most participants had substantial experience managing chronic illness. Regarding treatment profiles, 68% relied primarily on oral antidiabetic medication, whereas 32% combined oral medication with insulin therapy. The majority of respondents (72%) reported daily access to smartphones and internet services, supporting the feasibility of digital healthcare integration within the study population.

Participants utilized several forms of digital health technologies, including mobile applications, telemonitoring systems, and web-based diabetes management platforms. Mobile applications were identified as the most frequently used intervention because they provided practical features such as medication reminders, glucose tracking, dietary monitoring, and health education. The average frequency of digital health usage ranged from five to seven days per week, reflecting high engagement levels among respondents.

The most frequently accessed features included medication reminders (80%), blood glucose tracking tools (75%), and dietary management systems (65%). These findings indicate that participants primarily relied on digital technologies for behavioral support and routine monitoring activities associated with diabetes self-management.

Table 1. Demographic Characteristics and Digital Health Intervention Usage

Category	Value
Total Participants	150
Age Range	30–65 years
Mean Age	56 years
Gender Distribution	53% Male, 47% Female
Duration of Diabetes	>5 years (61%)
Main Therapy Type	Oral Medication (68%)
Daily Internet Access	72%
Digital Health Tools Used	Mobile Apps, Telemonitoring, Web-Based Platforms
Frequency of Usage	5–7 days per week
Most Accessed Features	Medication Reminders (80%), Blood Glucose Tracking (75%), Diet Management (65%)

Source: Primary Data Processed Using SPSS Version 26

The findings suggest that digital health technologies have become integrated into the routine healthcare activities of patients with T2DM. High utilization frequency indicates strong acceptance of technology-assisted disease management among participants.

Descriptive Statistics of Main Variables

Descriptive statistical analysis was conducted to identify the central tendencies and variability of the principal study variables, including digital intervention usage, medication adherence, self-efficacy, and HbA1c levels.

Table 2. Descriptive Statistics of Study Variables

Variable	Mean	SD	Minimum	Maximum
Digital Intervention Usage	4.18	0.73	2.10	5.00
Medication Adherence	6.92	1.04	3.00	8.00
Self-Efficacy	4.01	0.62	2.40	5.00
HbA1c Level	7.14	0.66	5.90	9.10

Source: Primary Data Processed Using SPSS Version 26

The results demonstrate that participants generally exhibited relatively high engagement with digital health interventions, reflected in the mean digital usage score of 4.18. Medication adherence also showed favorable levels, with an average MMAS-8 score approaching the upper range of the instrument. Similarly, self-efficacy scores indicate that respondents generally possessed strong confidence in managing diabetes-related self-care activities.

The average HbA1c level of 7.14% suggests moderate glycemic control among respondents. Although the value remains slightly above the ideal clinical threshold recommended for diabetes management, it indicates better glycemic outcomes compared with many chronic disease populations in similar healthcare contexts.

The relatively small standard deviation values across variables indicate moderate consistency among respondents, suggesting stable behavioral and clinical patterns within the study sample.

Correlation Between Digital Health Intervention Usage and Self-Management Outcomes

Pearson correlation analysis was performed to examine the relationships among digital intervention usage, medication adherence, self-efficacy, and HbA1c levels. The analysis aimed to determine whether increased digital health engagement was significantly associated with improved behavioral and clinical outcomes.

Table 3. Pearson Correlation Matrix

Variables	Digital Intervention Usage	Medication Adherence	Self-Efficacy	HbA1c Level
Digital Intervention Usage	1	0.624	0.548	-0.517
Medication Adherence	0.624	1	0.486	-0.432
Self-Efficacy	0.548	0.486	1	-0.471
HbA1c Level	-0.517	-0.432	-0.471	1

Source: Primary Data Processed Using SPSS Version 26

The results indicate a strong positive relationship between digital intervention usage and medication adherence ($r = 0.624$, $p < 0.01$). This finding suggests that patients who frequently utilized digital health technologies demonstrated greater consistency in following prescribed treatment regimens. Digital intervention usage also showed a significant positive correlation with self-efficacy ($r = 0.548$, $p < 0.01$). Patients who actively engaged with digital tools exhibited stronger confidence in performing self-care activities, including glucose monitoring, dietary regulation, and medication management. A significant negative correlation was identified between digital intervention usage and HbA1c levels ($r = -0.517$, $p < 0.01$). Because lower HbA1c values indicate better glycemic control, this finding demonstrates that frequent digital engagement contributes positively to diabetes management outcomes.

Medication adherence and self-efficacy were likewise negatively associated with HbA1c levels, indicating that stronger behavioral compliance and confidence significantly contribute to improved glycemic regulation.

Multiple Regression Analysis

Multiple linear regression analysis was conducted to examine the predictive influence of digital health intervention usage, medication adherence, and self-efficacy on HbA1c levels.

Table 4. Multiple Regression Model Summary

Model	R	R ²	Adjusted R ²	Std. Error	F	Sig.
1	0.701	0.491	0.481	0.542	46.52	<0.001

Source: Primary Data Processed Using SPSS Version 26

The regression model explained approximately 49.1% of the variance in HbA1c levels, indicating that digital intervention usage, medication adherence, and self-efficacy collectively represent substantial predictors of glycemic control. The statistically significant F-value confirms the robustness of the regression model.

Table 5. Regression Coefficients

Predictor Variables	B	Std. Error	β	t	Sig.
Constant	9.452	0.387	—	24.42	<0.001
Digital Intervention Usage	-0.321	0.062	-0.404	-5.18	<0.001
Medication Adherence	-0.287	0.078	-0.291	-3.68	<0.001
Self-Efficacy	-0.214	0.069	-0.227	-3.10	0.002

Source: Primary Data Processed Using SPSS Version 26

Digital intervention usage emerged as the strongest predictor of HbA1c reduction ($\beta = -0.404$, $p < 0.001$), indicating that increased engagement with digital technologies substantially improves glycemic control. Medication adherence and self-efficacy also significantly predicted HbA1c outcomes. The negative beta coefficients indicate inverse relationships with HbA1c levels, meaning that improvements in behavioral and digital engagement variables contribute directly to lower glycemic levels.

Regression Assumption Testing

Several statistical assumption tests were conducted to ensure the validity of the regression model.

Table 6. Regression Assumption Testing

Assumption Test	Result	Interpretation
Normality Test (Kolmogorov–Smirnov)	$p = 0.087$	Normal Distribution
Multicollinearity (VIF)	1.21–1.48	No Multicollinearity
Tolerance Values	0.67–0.82	Acceptable
Heteroscedasticity Test	$p > 0.05$	No Heteroscedasticity

Source: Primary Data Processed Using SPSS Version 26

The normality test confirmed that residual distributions were statistically normal. Variance Inflation Factor (VIF) values below 5 indicated the absence of multicollinearity among predictor variables. Likewise, tolerance values exceeded the minimum acceptable threshold, suggesting adequate independence among variables.

The heteroscedasticity analysis further demonstrated stable residual variance, indicating that the regression model satisfied key statistical assumptions required for reliable interpretation.

Comparison of HbA1c Levels Between Frequent and Infrequent Users

An independent samples t-test was conducted to compare HbA1c levels between frequent and infrequent users of digital health interventions.

Table 7. Independent Samples t-Test for HbA1c Levels

Group	N	Mean HbA1c (%)	SD	t	df	Sig.
Frequent Users	80	6.85	0.58	-6.12	148	<0.001
Infrequent Users	70	7.48	0.63			

Source: Primary Data Processed Using SPSS Version 26

Frequent users demonstrated significantly lower HbA1c levels compared with infrequent users. The mean difference of 0.63% indicates clinically meaningful improvement in glycemic control associated with regular digital engagement.

Effect size analysis using Cohen's d produced a value of 1.04, indicating a large practical effect. This finding demonstrates that the influence of digital health interventions extends beyond statistical significance and has substantial clinical relevance in diabetes management. The results consistently demonstrate that digital health interventions significantly improve medication adherence, strengthen self-efficacy, and reduce HbA1c levels among patients with Type 2 diabetes. The statistical findings provide strong empirical support for integrating digital healthcare technologies into chronic disease management systems, particularly within outpatient healthcare environments in developing countries.

Digital Health Interventions and the Transformation of Diabetes Self-Management

The results of this study indicate that digital health interventions (DHIs) have a meaningful impact on patients' self-management of Type 2 diabetes mellitus (T2DM), specifically medication adherence, self-efficacy and glycemic control. The findings maintain the global outlook of using technology in healthcare to become a necessary part of the approach to the management of chronic diseases in patient-centred health care systems. This positive association found between use of digital interventions and better HbA1c outcomes demonstrates that frequent use of digital platforms can support long-term behaviour change that directly impacts health outcomes.

A significant positive relationship between digital intervention use and medication adherence is consistent with prior research highlighting the importance of mobile health technologies to bolster treatment adherence. Telehealth systems and digital reminder applications can boost adherence to therapeutic regimens by offering continuous monitoring and real-time feedback, which enhances patients' consistency in following prescribed treatment, as reported by Sharma et al. (2024) and Janjua et al. (2021). Likewise, Newby et al. (2021) reported that automated digital interventions helped to increase behavioral maintenance by providing customized notifications and self-regulation support mechanisms. The findings of the present study further revealed that such effects still carry out in the context of healthcare in Indonesia, where the integration of healthcare into the digital world is still in the initial development phase. This context contribution is particularly peculiar, as there is still limited evidence from LMICs about digital diabetes management.

The following is another key finding: There is a strong correlation between digital health use and self-efficacy. Among patients who used digital tools regularly, there was a higher level of confidence in managing diabetes-related activities, such as glucose monitoring, diet, and medications. This result is similar to the theory suggested by Bandura's self-efficacy theory, in which it is hypothesized that repeated feedback, reinforcement of behavior, and self-monitoring increases people's self-efficacy to engage in health-related behaviors. A number of previous studies have also found that self-efficacy is a key factor in achieving successful chronic disease management (e.g., Warner and Schwarzer, 2024; Dolatabadi et al., 2022). However, much research prior to that was largely on educational interventions without a full integration of a digital behavioral support system. The present study is theoretically innovative because it demonstrates that digital technologies are not only used for information delivery but also as empowerment mechanisms for behavior, supporting psychological readiness for the long-term management of chronic diseases.

The regression analysis also found that digital intervention use was the most powerful predictor of glycemic control than medication adherence and self-efficacy. This discovery contrasts somewhat with earlier studies, which had placed adherence as being the primary factor in reducing HbA1c. The greater predictive power of digital engagement detected in this study indicates that technology driven healthcare

systems can have an impact across various behavioral components such as monitoring frequency, treatment adherence, and lifestyle regulation. This integrated influence may have led to the highest standardized beta coefficient for digital intervention being identified in the regression model. Therefore, the study provides a fresh empirical approach that digital health engagement can be an end in itself to achieve clinical improvement, and not just as a means to healthcare.

The results have practical consequences for healthcare management and policy making. Embedding digital health interventions into outpatient diabetes services could help to lower the burden of health services by encouraging patient self-management and decreasing the need for direct clinical supervision. Mobile apps, telemonitoring, and online learning resources can enhance care continuity and decrease inefficiencies for healthcare providers. The findings have additional implications for developing countries with inadequate human resources for health and limited access to chronic disease services. Therefore, investments in digital health infrastructure, digital literacy programs and integrated telehealth systems are key priorities for the policymaker to push sustainable chronic disease management.

The study also enriches the digital health literature by further supporting the empirical link between technological engagement and the patient-centered health outcomes. This study, in contrast with other research that has largely dealt with the technological aspects of the technology, considers the impact of clinical, behavioral, and psychological outcomes in the same analytical framework. The integrated approach is the key novelty of the study and improves the understanding of the impact of digital interventions on diabetes self-management.

This research can be limited due to its contributions. First, the cross-sectional design makes it impossible to make causal inferences about the relationship between the use of digital interventions and long-term glycemic outcomes. Second, partial reliance on self-report measures of behavior may have resulted in an element of response bias. Third, the study was carried out in urban outpatient clinics in Makassar and findings may not be generalizable to rural populations or clinics that do not have as much digital access.

Longitudinal or experimental research methods should thus be used to further explore the sustainability of digital health interventions for diabetes management. Other variables, including digital literacy; socioeconomic status; access to health care; and patient motivation, should also be explored in further studies to gain deeper insights into factors that impact adoption of technology and behavioral outcomes. Comparative analysis of the regions in healthcare and demographic groups would also offer more insights into the scalability and effectiveness of digital healthcare systems in chronic disease management.

CONCLUSION

Overall, this study provides evidence that digital health interventions make a significant difference in the self-management of patients with Type 2 diabetes mellitus, including their medication adherence, self-efficacy, and HbA1c levels. The results suggest that the use of digital platforms like mobile apps, telemonitoring systems, and web-based programmes has a positive effect on behaviour and clinical outcomes. The researchers found that being more likely to use digital interventions was the most powerful predictor of glycemic control, demonstrating the increasing role of technology in delivering health care.

From a theoretical perspective, this study brings together clinical, behavioral and psychological aspects in one analysis to the field of digital health and self-management. The study also builds on the current body of knowledge by empirically analyzing a healthcare context in Indonesia, where research on digital diabetes

management is still scarce. These findings have practical implications for the integration of digital healthcare systems into outpatient care to enhance patient-centred care and healthcare access. The study is cross sectional and uses self-reported behavioral data, however, these are strengths. Longitudinal studies and the examination of other factors (including digital literacy, socioeconomic status, and health care access) should be explored to bolster learning about sustainable digital health implementation moving forward.

REFERENCES

- Ahmed, M. M., Okesanya, O. J., Olaleke, N. O., Adigun, O. A., Adebayo, U. O., Oso, T. A., ... & Lucero-Prisno III, D. E. (2025, May). Integrating digital health innovations to achieve universal health coverage: promoting health outcomes and quality through global public health equity. In *Healthcare* (Vol. 13, No. 9, p. 1060). MDPI. <https://doi.org/10.3390/healthcare13091060>
- Alhuseen, O. A., Ismail, N. A., Hasan, L., & Embarak, F. (2023). A comprehensive review of modern methods to improve diabetes self-care management systems. *International Journal of Advanced Computer Science and Applications*, (9). <https://doi.org/10.14569/IJACSA.2023.0140920>
- Alotaibi, N., Wilson, C. B., & Traynor, M. (2025). Enhancing digital readiness and capability in healthcare: a systematic review of interventions, barriers, and facilitators. *BMC health services research*, 25(1), 500. <https://doi.org/10.1186/s12913-025-12663-3>
- Alruwaili, M. M., Shaban, M., & Elsayed Ramadan, O. M. (2023). Digital health interventions for promoting healthy aging: a systematic review of adoption patterns, efficacy, and user experience. *Sustainability*, 15(23), 16503. <https://doi.org/10.3390/su152316503>
- Arini, M., Sugiyo, D., & Permana, I. (2022). Challenges, opportunities, and potential roles of the private primary care providers in tuberculosis and diabetes mellitus collaborative care and control: a qualitative study. *BMC health services research*, 22(1), 215. <https://doi.org/10.1186/s12913-022-07612-3>
- Chao, D. P. (2023). Health-promoting lifestyle and its predictors among health-related and non-health-related university students in Taiwan: a cross-sectional quantitative study. *BMC Public Health*, 23(1), 827. <https://doi.org/10.1186/s12889-023-15760-2>
- Chen, S. M., & Wu, C. J. (2023). Investigating the effects of digital foot self-management program on enhancing self-efficacy and self-care behavior among community-dwelling older adults with type 2 diabetes: a randomized controlled trial. *Digital Health*, 9, 20552076231220791. <https://doi.org/10.1177/20552076231220791>
- Chong, C. J., Bakry, M. M., Hatah, E., Mohd Tahir, N. A., & Mustafa, N. (2025). Effects of mobile apps intervention on medication adherence and type 2 diabetes mellitus control: a systematic review and meta-analysis. *Journal of telemedicine and telecare*, 31(2), 157-173. <https://doi.org/10.1177/1357633x231174933>
- Dar, M. A., Maqbool, M., Ara, I., & Qadrie, Z. (2023). Preserving sight: Managing and preventing diabetic retinopathy. *Open Health*, 4(1), 20230019. <https://doi.org/10.1515/ohe-2023-0019>
- Dolatabadi, S., Bohlouli, B., & Amin, M. (2022). Associations between perceived self-efficacy and oral health behaviours in adolescents. *International journal of*

dental hygiene, 20(4), 593-600. <https://doi.org/10.1111/idh.12610>

- Dong, D. (2025). Self-determination theory perspectives on the influence of digital learning engagement on motivation in extracurricular learning activities: Considering the mediating role of digital self-efficacy. *Learning and Motivation*, 90, 102135. <https://doi.org/10.1016/j.lmot.2025.102135>
- Febriyanti, R. M., Irawan, A. A., Anggriani, N., Andriyana, Y., & Abdulah, R. (2025). Challenges in implementing Indonesia's community-based chronic disease management program (Prolanis): A scoping review. *AIMS Public Health*, 12(3), 890. <https://doi.org/10.3934/publichealth.2025045>
- Figueiredo, T., Alcântara, L., Carrilho, J., Paúl, C., & Costa, E. (2025). Understanding adherence to digital health technologies: systematic review of predictive factors. *Journal of Medical Internet Research*, 27, e77362. <https://doi.org/10.2196/77362>
- Firoozi, A. A., & Firoozi, A. A. (2025). Navigating the Complex Landscape of Healthcare Innovation: Strategies for Overcoming Design and Implementation Challenges. In *Transformative Design in Healthcare: Infection Control and Patient Well-being through Architectural Innovation* (pp. 379-439). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-032-08019-6_9
- Hall, A. M., Allgar, V., Carroll, C. B., & Meinert, E. (2025). Digital health technologies and self-efficacy in Parkinson's: a scoping review. *BMJ open*, 15(1), e088616. <https://doi.org/10.1186/s12889-023-15760-2>
- Hall, E., Davis, K., Ohrnberger, J., Pickles, M., Gregson, S., Thomas, R., ... & Hauck, K. (2024). Associations between HIV stigma and health-related quality-of-life among people living with HIV: cross-sectional analysis of data from HPTN 071 (PopART). *Scientific reports*, 14(1), 12835. <https://doi.org/10.1038/s41598-024-63216-3>
- Hamidi, S., Gholamnezhad, Z., Kasraie, N., & Sahebkar, A. (2022). The effects of self-efficacy and physical activity improving methods on the quality of life in patients with diabetes: A systematic review. *Journal of Diabetes Research*, 2022(1), 2884933. <https://doi.org/10.1155/2022/2884933>
- Janjua, S., Carter, D., Threapleton, C. J., Prigmore, S., & Disler, R. T. (2021). Telehealth interventions: remote monitoring and consultations for people with chronic obstructive pulmonary disease (COPD). *Cochrane database of systematic reviews*, (7). <https://doi.org/10.1002/14651858.cd013196.pub2>
- Kosiol, J., Silvester, T., Cooper, H., Alford, S., & Fraser, L. (2024). Revolutionising health and social care: innovative solutions for a brighter tomorrow—a systematic review of the literature. *BMC health services research*, 24(1), 809. <https://doi.org/10.1186/s12913-024-11099-5>
- Kulkarni, A., Thool, A. R., & Daigavane, S. (2024). Understanding the clinical relationship between diabetic retinopathy, nephropathy, and neuropathy: a comprehensive review. *Cureus*, 16(3). <https://doi.org/10.7759/cureus.56674>
- Kurnia, A., Said, F., & Paduragan, S. L. (2025). Experience of burden in self-care of type 2 diabetes mellitus: a qualitative study in Indonesian context. *The Malaysian Journal of Nursing (MJN)*, 16(4), 33-44. <https://doi.org/10.31674/mjn.2025.v16i04.004>
- Li, Z., Lei, Y., Bui, Q., DePaul, O., Nicol, G. E., Mohr, D. C., ... & Wong, A. W. (2024). A digital intervention to promote self-management self-efficacy among

- community-dwelling individuals with stroke: pilot randomized controlled trial. *JMIR Rehabilitation and Assistive Technologies*, 11, e50863. <https://doi.org/10.2196/50863>
- Liu, C., Messer, M., Linardon, J., & Fuller-Tyszkiewicz, M. (2025). Applying models of self-regulated learning to understand engagement with digital health interventions: a narrative review. *Frontiers in Digital Health*, 7, 1380088. <https://doi.org/10.3389/fdgth.2025.1380088>
- Motaghi, S., Boogar, I. R., Moradi, S., & Asl, N. S. (2023). The effectiveness of cognitive behavioral stress management on health-related quality of life, diabetes management self-efficacy, and treatment adherence in type 2 diabetes. *Iranian journal of diabetes and obesity*. <https://doi.org/10.18502/ijdo.v15i1.12207>
- Newby, K., Teah, G., Cooke, R., Li, X., Brown, K., Salisbury-Finch, B., ... & Williams, S. L. (2021). Do automated digital health behaviour change interventions have a positive effect on self-efficacy? A systematic review and meta-analysis. *Health psychology review*, 15(1), 140-158. <https://doi.org/10.1080/17437199.2019.1705873>
- Osunde, R. N., Olorunfemi, O., Edwards, O. S., Oduyemi, R. O., & Sodimu, J. O. (2025). Transforming Diabetes Management: Optimizing Blood Glucose Control through Lifestyle Strategies for Better Health Outcomes—Scoping Review. *Bangladesh Journal of Endocrinology and Metabolism*, 4(1), 18-25.
- Park, G., Lee, H., Lee, M. J., & Khang, A. (2025). Impact of Mobile App-Based Self-Monitoring Engagement on Self-Care Self-Efficacy, Health Behaviors, and Hemoglobin A1c Among Patients With Type 2 Diabetes Mellitus: A Secondary Analysis of a Randomized Controlled Trial. *Western Journal of Nursing Research*, 47(12), 1180-1192. <https://doi.org/10.1177/01939459251374937>
- Patel, S. B., Iqbal, F. M., Lam, K., Acharya, A., Ashrafian, H., & Darzi, A. (2025). Characterizing Behaviors that influence the implementation of digital-based interventions in health care: systematic review. *Journal of medical Internet research*, 27, e56711. <https://doi.org/10.2196/56711>
- Rahadian Syah, D. Z., Winahyu Sari, I. W., & Adinugraha, T. S. (2025). Delivering Integrated Diabetes Care: Nursing Management Experiences in a Primary Health Center Model in Indonesia. *Philippine Journal of Nursing*, 95(1).
- Rubab, H., Aziz, F., Gul, R., & Froelicher, E. S. (2025). Effect of a structured educational intervention delivered through a mobile application on glycated haemoglobin and self-efficacy in adolescents with type 1 diabetes mellitus: a systematic review and meta-analysis. *BMJ open*, 15(9), e093798. <https://doi.org/10.1136/bmjopen-2024-093798>
- Sharma, V., Feldman, M., & Sharma, R. (2024). Telehealth technologies in diabetes self-management and education. *Journal of diabetes science and technology*, 18(1), 148-158. <https://doi.org/10.1177/19322968221093078>
- Sofyan, H., Diba, F., Susanti, S. S., Marthoenis, M., Ichsan, I., Sasmita, N. R., ... & Vollmer, S. (2023). The state of diabetes care and obstacles to better care in Aceh, Indonesia: a mixed-methods study. *BMC Health Services Research*, 23(1), 271. <https://doi.org/10.1186/s12913-023-09288-9>
- Wang, Q., Su, M., Zhang, M., & Li, R. (2021). Integrating digital technologies and public health to fight Covid-19 pandemic: key technologies, applications, challenges and outlook of digital healthcare. *International Journal of*

Environmental Research and Public Health, 18(11), 6053.
<https://doi.org/10.3390/ijerph18116053>

Warner, L. M., & Schwarzer, R. (2024). Self-efficacy and health. In *Handbook of concepts in health, health behavior and environmental health* (pp. 1-26). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-97-0821-5_15-1

Willis, V. C., Thomas Craig, K. J., Jabbarpour, Y., Scheufele, E. L., Arriaga, Y. E., Ajinkya, M., ... & Bazemore, A. (2022). Digital health interventions to enhance prevention in primary care: scoping review. *JMIR medical informatics*, 10(1), e33518. <https://doi.org/10.2196/33518>