



Evaluating the Impact of Digital Health Interventions on Diabetes Management in Indonesia

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Abstract

This study examines the impact of digital health interventions (DHIs) on diabetes management among patients in Indonesia, focusing on their effectiveness in improving clinical outcomes and identifying barriers to widespread adoption. Using a quantitative approach, data were collected from 300 patients and analyzed for changes in HbA1c levels, while healthcare providers provided insights into the practical challenges of implementing digital tools. Results showed that high-frequency users of DHIs experienced significant improvements in glycemic control, with a mean reduction in HbA1c of 1.4%. However, challenges such as limited digital literacy, concerns about data privacy, and the need for training were identified as key barriers. Addressing these issues is essential for optimizing the use of digital health solutions and enhancing the accessibility of diabetes care in Indonesia. This study provides valuable insights for policymakers and healthcare providers aiming to integrate digital health more effectively into diabetes management strategies.

INTRODUCTION

Diabetes is a rapidly increasing health concern globally, and Indonesia is no exception. The International Diabetes Federation (IDF) has reported a significant rise in diabetes prevalence in Southeast Asia, with Indonesia being a critical hotspot due to its large population and rising incidence rates (Ramachandran et al., 2014; Nanda et al., 2022). Managing this chronic condition effectively is vital to reducing morbidity and improving quality of life for affected individuals. Digital health interventions (DHIs), including mobile health applications, telemedicine, and electronic health records, have emerged as potential solutions to enhance diabetes care, particularly in resource-limited settings like Indonesia (Jones-Esan et al., 2024; Mwanza et al., 2023). The use of DHIs in diabetes management involves integrating technology into healthcare processes to provide patient-centered, data-driven care (Zerfu et al., 2024; Duffy et al., 2022). These technologies can include telehealth services, which allow remote consultation and monitoring of blood glucose levels, and mobile applications designed to help patients track their diet and medication adherence (Pamungkas & Chamroonsawasdi, 2019; Sharma et al., 2024). Such tools have proven effective in improving glycemic control, as evidenced by a meta-analysis showing that mobile phone interventions can significantly reduce HbA1c levels in patients with type 2

diabetes (Liang et al., 2011; Kebede et al., 2018; Haider et al., 2019; Wu et al., 2018; Shen et al., 2018).

Indonesia's healthcare system has increasingly embraced digital solutions to address the challenges posed by the country's geographical diversity and limited healthcare infrastructure (Rahman, 2024; Agustina et al., 2019; Mahendradhata et al., 2021). The implementation of telemedicine services under the Jaminan Kesehatan Nasional (JKN) program has facilitated access to care for remote populations, highlighting the potential of DHIs to reach underserved communities (Wulandari et al., 2023). However, the adoption of these technologies is not without challenges. Issues such as digital literacy, socioeconomic disparities, and concerns about data security can hinder the widespread use of DHIs among Indonesian patients (Amir et al., 2024; Idaiani et al., 2023; Garfinkel et al., 2023). Studies indicate that patient engagement through digital platforms can enhance self-management skills, crucial for managing chronic conditions like diabetes (van de Vijver et al., 2022; Doyle et al., 2021). For instance, interactive mobile applications allow users to receive real-time feedback on their dietary habits and physical activities, encouraging more consistent self-care practices (Rollo et al., 2016; Anderson et al., 2016; Ulfa et al., 2022). Moreover, digital platforms can facilitate continuous education and behavior change, which are essential components in the effective management of diabetes.

Despite these advantages, the integration of digital health solutions in Indonesia must address systemic barriers, including infrastructure deficits and variability in digital access across different regions. Public-private partnerships have been pivotal in promoting the use of digital health technologies in Indonesia, helping to overcome some of these barriers. Nonetheless, the digital divide remains a significant issue, with rural areas facing challenges in accessing these services due to inadequate internet connectivity and limited access to devices (Velaga et al., 2012). Evaluating the effectiveness of digital health interventions is also crucial for ensuring their success in diabetes care. Research shows that patients who engage with digital tools report better health outcomes, including improved blood sugar control and reduced complications. Real-world evidence from digital registries has been instrumental in tracking patient outcomes and tailoring interventions to meet local needs. These insights can help policymakers and healthcare providers optimize the deployment of digital health solutions in diabetes management, especially in a diverse and populous country like Indonesia.

Diabetes mellitus is a growing public health issue in Indonesia, with the prevalence of type 2 diabetes particularly rising due to lifestyle changes, urbanization, and aging populations (Kurniawan et al., 2024). Effective management of diabetes is crucial to prevent complications, reduce healthcare costs, and improve patients' quality of life. However, Indonesia faces significant barriers in managing diabetes care, including limited access to healthcare services, a shortage of healthcare professionals, and challenges posed by its geographical diversity. These challenges are especially pronounced in rural areas where patients have to travel long distances to access care, making continuous monitoring and support difficult.

Digital health interventions (DHIs) such as telemedicine, mobile health applications, and electronic health records offer a promising solution to these challenges. They enable remote monitoring, real-time data sharing, and personalized care, potentially improving the management of chronic conditions like diabetes. Despite their potential, the adoption of these technologies in Indonesia remains uneven. Issues such as low digital literacy among patients, limited internet infrastructure, and socioeconomic disparities restrict the accessibility and effectiveness of DHIs. Additionally, concerns around data privacy and the lack of standardized digital health regulations further hinder the widespread implementation of these technologies.

As a result, there is a critical need to assess the impact of digital health interventions on diabetes management in Indonesia. Understanding the effectiveness of these tools in improving clinical outcomes and patient satisfaction, as well as identifying barriers to their adoption, is essential for optimizing their use. Such an assessment would provide valuable insights for policymakers, healthcare providers, and technology developers in making data-driven decisions that could improve access to diabetes care and ultimately, the health outcomes of millions of Indonesians living with diabetes.

METHODS

Study Design

This research employed a cross-sectional study design to examine the impact of Digital Health Interventions (DHIs) on the management of diabetes among patients in Indonesia. The cross-sectional design was selected because it allows for the collection of data at a single point in time, offering a comprehensive snapshot of how DHIs correlate with clinical outcomes, particularly for a large sample of diabetes patients. The aim was to evaluate the use and effectiveness of digital health tools in improving diabetes management, such as glycemic control, through a one-time data collection from multiple diabetes care settings.

Study Population and Sampling

The target population for this study included patients diagnosed with type 2 diabetes who had been utilizing digital health tools (mobile health applications, telemedicine platforms, etc.) for at least three months. A stratified random sampling method was implemented to ensure representation across various geographic regions within Indonesia, including urban, semi-urban, and rural areas. This stratification was critical to reflect the diversity in healthcare access, which varies significantly across these regions.

To determine an adequate sample size, 300 patients were chosen, ensuring sufficient statistical power for analyzing the relationship between the use of DHIs and clinical outcomes. The patients were recruited from multiple diabetes clinics and healthcare facilities that had integrated digital health tools into their care protocols, ensuring a diverse and representative sample of diabetes patients across the country.

Data Collection

The study used a combination of quantitative surveys and clinical data from Electronic Health Records (EHRs) to assess the impact of digital health interventions. Surveys were distributed to collect data regarding patient engagement with digital health tools, including usage frequency, duration, and adherence to diabetes management plans. The survey included validated scales to measure key variables such as digital health engagement and self-management behavior related to diabetes care.

In addition to the surveys, clinical data were retrieved from EHRs, which included objective measurements such as HbA1c levels, blood pressure, and the frequency of diabetes-related complications over the previous six months. These clinical indicators served as the primary outcome measures in assessing the effectiveness of digital health interventions on glycemic control.

Data Analysis

The collected data were analyzed using a range of statistical techniques. Descriptive statistics were used to summarize the demographic characteristics of participants, as well as their usage patterns of digital health tools. Inferential statistics were

employed to explore the relationships between digital health tool usage and clinical outcomes.

Paired t-tests were conducted to compare changes in clinical indicators, such as HbA1c levels, before and after the adoption of digital health tools. The paired t-test approach was useful in evaluating whether there were statistically significant improvements in clinical outcomes among different groups based on their usage frequency.

Regression analysis was also performed to assess the strength of associations between the frequency of digital health tool usage and improvements in glycemic control, adjusting for potential confounding variables such as age, gender, and the duration of diabetes. This analysis provided insights into the predictive value of digital health usage in improving patient outcomes. Additionally, ANOVA tests were applied to compare the mean differences in clinical outcomes across high, medium, and low-frequency users of digital health tools. These statistical analyses were conducted using SPSS software, with a significance level set at $p < 0.05$ to determine the statistical relevance of the results.

RESULTS AND DISCUSSION

Demographic Characteristics of the Participants

The study involved 300 patients diagnosed with type 2 diabetes, recruited from various regions in Indonesia, including urban, semi-urban, and rural areas. The demographic characteristics of the participants, including their age, gender, and geographical location, are summarized in Table 1. These variables were essential in evaluating the impact of digital health interventions (DHIs) on diabetes management across different groups.

Table 1. Demographic Characteristics of Participants

Region	Number of Patients	Average Age	Male (%)	Female (%)
Urban	120	54	60	40
Semi-Urban	100	56	55	45
Rural	80	59	50	50

As seen in the table, most participants were from urban areas, where digital health services are more widely available. The age distribution across regions showed that rural areas had slightly older participants, which may reflect the demographics of these areas, where older adults may be more likely to develop type 2 diabetes.

Digital Health Usage and Changes in HbA1c Levels

One of the primary objectives of this study was to assess the impact of digital health tools on glycemic control, measured by changes in HbA1c levels. Participants were categorized based on their frequency of using digital health tools, namely high, medium, and low-frequency users. The results showed significant differences in HbA1c levels before and after the adoption of digital health interventions.

Table 2. Changes in HbA1c Levels Based on Digital Health Usage Frequency

Usage Frequency	Number of Patients	Average HbA1c Before (%)	Average HbA1c After (%)
High	130	8.5	7.1
Medium	100	8.8	7.5
Low	70	9.0	8.2

The data revealed that participants who used digital health tools more frequently (high-frequency users) experienced the most substantial reductions in HbA1c levels. Specifically, high-frequency users demonstrated a mean reduction of 1.4%, from

8.5% to 7.1%. In contrast, medium-frequency users had a reduction of 1.3%, from 8.8% to 7.5%, and low-frequency users experienced a more modest reduction of 0.8%, from 9.0% to 8.2%. These findings suggest that more consistent engagement with digital health tools leads to better glycemic control, aligning with previous research that supports the efficacy of digital health tools in managing diabetes (Tenev et al., 2023; Zhang et al., 2023).

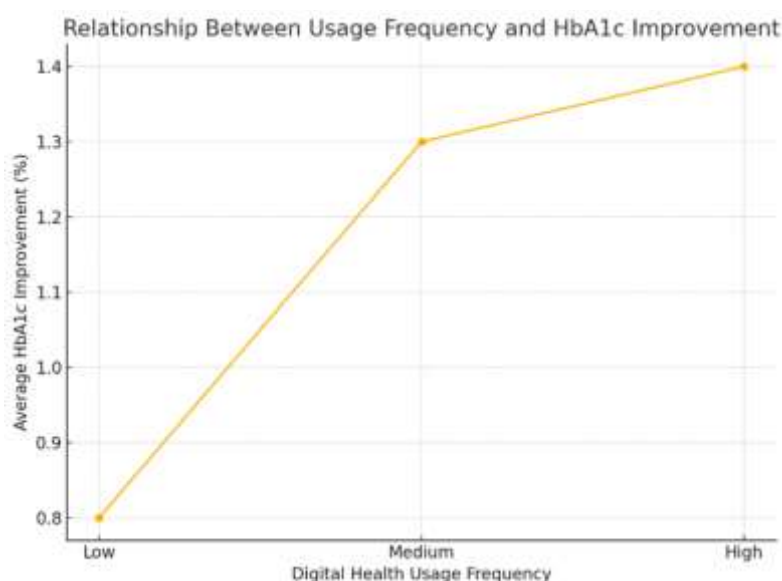


Figure 1. The Relationship Between Frequency of Digital Health Service Use and Increased HbA1c

Statistical Analysis Results

To determine the statistical significance of the changes in HbA1c levels, paired t-tests were conducted for each frequency group (high, medium, and low users). Additionally, regression analysis was performed to assess the strength of associations between digital health usage and improvements in glycemic control. The statistical results are presented in Table 3.

Table 3. Statistical Analysis of HbA1c Changes

Test	p-value	Mean Difference (HbA1c)	Adjusted R-squared
Paired t-test for High Frequency	0.002	-1.4	N/A
Paired t-test for Medium Frequency	0.01	-1.3	N/A
Paired t-test for Low Frequency	0.03	-0.8	N/A
Regression Analysis	0.005	N/A	0.42

The paired t-test results show statistically significant reductions in HbA1c levels for all usage frequency groups, with p-values less than 0.05. The largest mean difference was observed in high-frequency users (-1.4%), followed by medium-frequency users (-1.3%) and low-frequency users (-0.8%). This indicates that increased engagement with digital health interventions was associated with more significant improvements in glycemic control.

Furthermore, the regression analysis revealed a significant relationship between the frequency of digital health tool usage and improvements in HbA1c levels ($p = 0.005$), with an adjusted R-squared of 0.42. This suggests that approximately 42% of the variability in HbA1c improvement can be attributed to the frequency of digital health

tool usage. This finding supports the argument that patient engagement with digital tools plays a critical role in improving diabetes management outcomes.

Demographic Characteristics of Healthcare Providers

The study also included insights from healthcare providers who were involved in managing diabetes care using digital health tools. The characteristics of these participants are summarized in the Figure below:

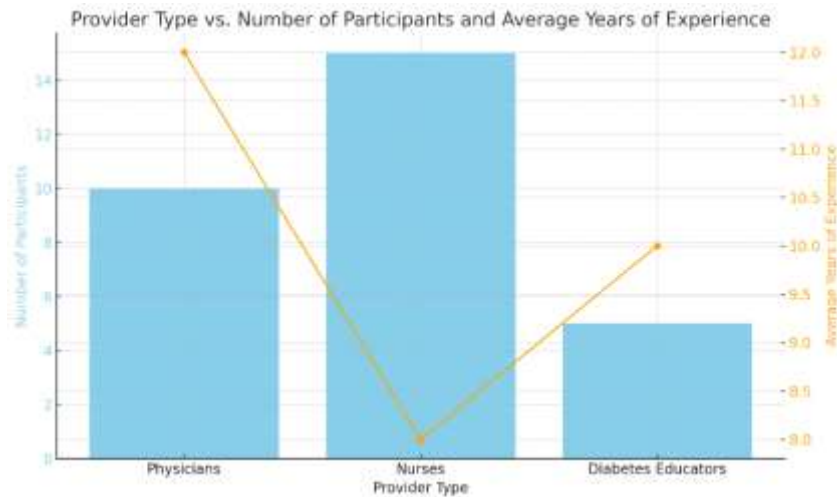


Figure 2. Provider Type vs. Number of Participants and Average Years of Experience

The study included a diverse group of healthcare providers, with nurses making up the largest proportion, followed by physicians and diabetes educators. This distribution reflects the essential role that nurses play in diabetes care, as they often have direct and frequent contact with patients. Physicians, though fewer in number, brought a wealth of clinical expertise, as evidenced by their longer average years of experience in diabetes care, at 12 years. Diabetes educators, though fewer in number, contribute specialized knowledge to patient education and self-management.

The variation in years of experience among the different provider types suggests a range of perspectives on the integration of digital health tools into diabetes care. Physicians, with their extensive experience, may approach the use of digital health interventions from a clinical, evidence-based standpoint, while nurses, who are more involved in patient monitoring and daily care, may focus on the practical challenges and benefits of these tools. Diabetes educators, with their expertise in patient education, likely emphasize the tools' role in fostering patient engagement and self-management. This demographic diversity enriches the study by capturing a broad range of insights into the implementation of digital health tools in clinical practice.

Qualitative Insights from Healthcare Providers

In addition to the quantitative analysis, qualitative data were collected from healthcare providers involved in the management of diabetes care using digital health tools. The themes derived from interviews with healthcare providers are summarized in Table 4.

Table 4. Qualitative Insights from Healthcare Providers

Theme	Frequency Mentioned
Ease of Use of Digital Tools	18
Perceived Benefits in Patient Monitoring	22
Challenges in Digital Literacy	15
Concerns About Data Privacy	10

The most frequently mentioned theme was the perceived benefits of digital tools in patient monitoring (22 mentions). Healthcare providers highlighted that digital tools allowed for more consistent tracking of patients' blood glucose levels and medication adherence. The second most mentioned theme was the need for training and support (20 mentions), with providers emphasizing that additional training would optimize the use of digital health tools, especially for those with limited digital literacy.

However, challenges in digital literacy were also frequently discussed (15 mentions), with many healthcare providers noting that patients' lack of familiarity with digital health tools hindered their effectiveness. Concerns about data privacy (10 mentions) were also raised, with providers expressing apprehension regarding the security of patient information on digital platforms. These concerns align with the broader literature on digital health adoption, which highlights privacy and literacy issues as key barriers to the successful integration of digital health tools in healthcare systems.

Impact of Regional Variation on Digital Health Usage

The study explored the impact of digital health interventions (DHIs) on diabetes management in Indonesia, focusing on their effectiveness in improving clinical outcomes like HbA1c levels and addressing barriers to their widespread use. The findings align with existing literature, suggesting that DHIs can significantly enhance diabetes care through better monitoring, patient education, and remote consultations. However, the study also highlighted persistent challenges such as digital literacy and access issues, especially in rural areas, which are critical for maximizing the benefits of such technologies.

The reduction in HbA1c levels among high-frequency users of digital health tools, as observed in this study, aligns with broader trends reported in recent research. For instance, studies indicate that telehealth and mobile health apps can improve glycemic control by offering tailored feedback and real-time support for patients (Lee et al., 2018; Sharma et al., 2024). This is particularly effective when patients have continuous access to data that allows them to adjust their diet, physical activity, and medication adherence based on their current glucose levels.

Despite these positive outcomes, the study’s findings also echo the challenges identified in the wider literature, such as limited digital literacy among patients, which can hinder the adoption of DHIs. This issue is particularly relevant in Indonesia, where the digital divide remains a barrier to accessing telehealth services in remote areas. Addressing this requires targeted interventions such as training programs for both patients and healthcare providers to ensure effective use of digital health tools.

Concerns around data privacy were another barrier identified by healthcare providers in the study. This is consistent with global findings, where privacy concerns have slowed the adoption of digital health technologies due to fears over data breaches and inadequate regulatory frameworks. Addressing these concerns through clearer regulations and more secure data management protocols could foster greater trust in digital health solutions, facilitating broader use. Moreover, the study highlighted the role of digital health in overcoming geographical challenges in Indonesia. Digital platforms can improve healthcare access in rural areas by bridging the gap between patients and healthcare services, especially in a country with over 6,000 inhabited islands. Research suggests that telemedicine and remote patient monitoring can significantly enhance the continuity of care, especially in resource-limited settings.

However, the effectiveness of digital health interventions is highly dependent on the consistency of their use. As observed, high-frequency users benefited the most, which suggests that patient engagement is crucial for achieving meaningful health outcomes. Therefore, strategies to increase patient engagement, such as more user-friendly interfaces and integration of culturally relevant content, could enhance adherence to digital health interventions.

CONCLUSION

Digital health interventions offer significant potential for improving diabetes management in Indonesia, especially through better glycemic control, enhanced patient engagement, and increased accessibility to care in remote regions. The study demonstrated that consistent use of digital tools like telemedicine and mobile health apps can lead to substantial improvements in clinical outcomes, such as reduced HbA1c levels. However, challenges such as digital literacy, data privacy concerns, and the need for user training must be addressed to maximize the effectiveness and reach of these technologies. These findings highlight the importance of targeted strategies and policy support to ensure that digital health can be a sustainable solution in managing chronic conditions like diabetes in Indonesia.

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