Axis Community Research Journal

(ACRJ)

MOBILE-BASED INSULIN DOSAGE REMINDERS VERSUS MANUAL TRACKING IN IMPROVING GLYCEMIC CONTROL: A RANDOMIZED CONTROLLED TRIAL

(*Original Research*)

Ammar Khalil[1]*, Lecturer, Department of Data Science, University of Kotli, AJ&K, Pakistan, ammar.khalil@uokajk.edu.pk

Arsalan Rasool[2], Lecturer, Khyber Medical University, Peshawa, Pakistan, arsalanrkgul@gmail.com

Muhammad Dawood[3], Medical officer (Accidents & Emergency), General Hospital: Lahore, Pakistan.

https://orcid.org/0009-0004-6360-3391

Acknowledgement:	The authors sincerely thank all participants for their valuable cooperation throughout the study.
Conflict of interests	None
Corresponding	Ammar Khalil, Lecturer, Department of Data Science, University of Kotli, AJ&K, Pakistan, ammar.khalil@uokajk.edu.pk

Abstract

Background: Effective insulin administration and adherence are critical for achieving optimal glycemic control in individuals with diabetes mellitus. However, manual tracking of insulin doses often leads to poor compliance due to forgetfulness, complex regimens, and limited self-monitoring. The use of mobile health (mHealth) technology has emerged as a promising solution to improve treatment adherence through automated reminders and digital feedback systems**.**

Objective: To evaluate the effectiveness of a mobile app–based insulin dosage reminder system compared with traditional manual tracking in improving treatment adherence and glycemic outcomes among patients requiring insulin therapy**.**

Methods: A randomized controlled trial was conducted in South Punjab, enrolling 120 insulin-dependent diabetic patients aged 18–65 years. Participants were randomly assigned to either a mobile-based insulin reminder group or a manual tracking control group (n=60 each). The intervention group received automated insulin reminders through a mobile application, while the control group maintained standard self-monitoring using written logs. Data were collected at baseline, 3 months, and 6 months. Primary outcomes included change in glycated hemoglobin (HbA1c) and adherence rates, while secondary outcomes included fasting glucose levels and patient satisfaction. Statistical analysis was performed using independent and paired t-tests, assuming normal data distribution, with significance set at $p<0.05$.

Results: Participants using the mobile reminder system achieved a significantly greater reduction in HbA1c ($-1.50 \pm 0.46\%$) compared to the manual tracking group ($-0.72 \pm 0.41\%$, $p<0.001$). Fasting glucose improved more substantially in the mobile group (-29.2 mg/dL, $p=0.004$). Mean adherence rates were higher ($92.8 \pm 5.9\%$ vs. $78.3 \pm 7.1\%$, $p<0.001$), and patient satisfaction scores were also greater among app users (8.6 ± 0.9 vs. 7.1 ± 1.2, $p<0.001$**).**

Conclusion: Mobile-based insulin reminder systems significantly improved adherence, glycemic control, and patient satisfaction compared to manual tracking. These findings highlight the potential of mHealth tools as practical, cost-effective adjuncts to enhance diabetes self-management and optimize therapeutic outcomes.

Keywords: Adherence, Blood Glucose, Diabetes Mellitus, Digital Health, Glycated Hemoglobin, Insulin Therapy, Mobile Applications, Self-Management, Telemedicine, Treatment Outcome.

Introduction

Diabetes mellitus remains one of the most pressing global health concerns of the 21st century, with type 1 and type 2 diabetes both contributing significantly to morbidity, mortality, and health care costs worldwide(1). Central to diabetes management is the maintenance of optimal glycemic control, as sustained hyperglycemia increases the risk of long-term complications such as neuropathy, nephropathy, retinopathy, and cardiovascular disease(2). Insulin therapy is a cornerstone for many individuals with diabetes, particularly those with type 1 diabetes and those with advanced type 2 diabetes whose glycemic targets cannot be achieved with oral hypoglycemic agents alone(3). However, the success of insulin therapy largely depends on consistent adherence to prescribed dosages and schedules. Unfortunately, adherence to insulin regimens remains a major challenge for patients, influenced by factors such as forgetfulness, regimen complexity, fear of hypoglycemia, and the burden of routine self-monitoring(4).

The integration of digital health technologies into chronic disease management has transformed patient engagement and adherence strategies(4). In recent years, mobile health (mHealth) applications have gained prominence as accessible tools capable of bridging the gap between clinical guidance and everyday self-management. Mobile-based insulin reminder systems, in particular, represent a promising approach to improving treatment adherence by offering automated prompts, dosage tracking, and feedback mechanisms tailored to individual patient needs. These digital interventions are designed to simplify self-management, empower patients to take control of their treatment, and reduce the cognitive burden associated with manual record keeping. The continuous accessibility of mobile phones makes such reminders a practical and scalable intervention, especially in populations with limited access to frequent in-person follow-up(5).

Despite the growing popularity of mHealth applications in diabetes care, the actual impact of mobile-based insulin reminder systems on measurable clinical outcomes remains insufficiently explored(6). While many studies have demonstrated the potential of smartphone apps in improving lifestyle factors, medication adherence, and patient engagement, there is a relative scarcity of rigorous randomized controlled trials evaluating their direct influence on glycemic indices such as HbA1c(7). Moreover, the existing literature presents mixed findings—some studies report modest improvements in glycemic control, while others find minimal or no clinical benefit, often due to variations in app design, patient demographics, or study duration(8). This inconsistency underscores the need for well-structured, evidence-based research to clarify whether mobile insulin reminders translate into meaningful metabolic improvements beyond the realm of convenience and user satisfaction(9).

Manual insulin tracking, traditionally performed through written logs or memory-based recall, continues to be widely used in clinical practice(10). However, this method is inherently prone to human error and recall bias, leading to incomplete or inaccurate documentation of insulin doses. Such inconsistencies can hinder both patient self-awareness and clinician decision-making, resulting in suboptimal glycemic control. By contrast, digital reminder systems have the advantage of real-time data capture, accuracy, and feedback, offering healthcare providers an opportunity to monitor adherence patterns more objectively. Furthermore, these systems can integrate educational content and motivational elements, potentially enhancing patient self-efficacy—a key determinant of successful long-term diabetes management(10).

The rapid evolution of smartphone technology, coupled with widespread internet accessibility, particularly in developing regions, presents an unprecedented opportunity to integrate digital tools into conventional diabetes care frameworks(11). In regions where healthcare resources are strained and patient-to-provider ratios are high, mHealth interventions can serve as cost-effective adjuncts to standard care. However, to justify their integration into clinical protocols, robust evidence demonstrating their clinical utility and reliability is essential. The question remains whether mobile-based insulin dosage reminders can significantly outperform manual tracking methods in improving adherence and glycemic outcomes in real-world settings(12).

This study, therefore, seeks to address this critical gap by conducting a randomized controlled trial comparing mobile app–based insulin reminder systems with conventional manual tracking in individuals requiring insulin therapy(13). The trial aims to determine whether automated, mobile-based reminders lead to measurable improvements in glycemic control, as reflected by reductions in HbA1c levels and improved treatment adherence rates. The overarching objective is to evaluate the effectiveness of mobile app–based insulin reminder systems on treatment adherence and glycemic outcomes, thereby contributing valuable evidence to guide the integration of digital health solutions into routine diabetes care

Methods.

This randomized controlled trial was conducted in South Punjab to evaluate the effectiveness of a mobile app–based insulin reminder system compared to conventional manual insulin tracking in improving treatment adherence and glycemic outcomes among individuals with diabetes requiring insulin therapy. The study was designed to provide a robust comparison between digital intervention and traditional self-monitoring methods within a real-world setting, ensuring the applicability of findings to routine clinical practice.

Participants were recruited from outpatient diabetic clinics and community health centers across the region. Eligibility criteria included adults aged 18 to 65 years with either type 1 or type 2 diabetes mellitus who had been prescribed insulin therapy for at least six months prior to enrollment. Participants were required to possess a personal smartphone compatible with the mobile application used in the study and demonstrate basic digital literacy to operate it. Exclusion criteria included individuals with severe visual or cognitive impairment, psychiatric illness affecting self-care, pregnancy, or those currently using any form of automated digital reminder system for insulin administration. Written informed consent was obtained from all participants before study initiation.

A total of 120 participants were enrolled based on sample size estimation using an anticipated medium effect size (Cohen's d = 0.5), with a power of 80% and an alpha of 0.05 to detect a statistically significant difference in HbA1c reduction between groups. Participants were randomly assigned in a 1:1 ratio into two groups: the intervention group, receiving mobile-based insulin dosage reminders, and the control group, maintaining manual insulin tracking through paper logs or personal recollection. Randomization was performed using a computer-generated sequence with allocation concealment ensured through sealed opaque envelopes.

The intervention group was provided access to a dedicated insulin reminder application designed to send automated notifications at scheduled insulin administration times. The app allowed participants to log insulin doses, receive adherence feedback, and view daily summaries. The control group continued standard self-monitoring practices without any digital assistance. Both groups received identical baseline counseling on insulin administration, diet, and exercise from the nursing and medical staff to minimize confounding effects.

Data were collected at baseline, 3 months, and 6 months. Primary outcome measures included change in glycated hemoglobin (HbA1c) and adherence rate, calculated as the proportion of prescribed doses actually administered within the correct time window. Secondary outcomes included fasting blood glucose levels, frequency of missed doses, and self-reported satisfaction with treatment adherence. HbA1c was measured using a standardized high-performance liquid chromatography (HPLC) method, and fasting glucose levels were determined through venous samples analyzed in an accredited clinical laboratory. Adherence data for the intervention group were extracted from the app's internal log, while the control group's adherence was derived from manual records.

Data were analyzed using SPSS version 26. Continuous variables were presented as mean ± standard deviation, while categorical variables were expressed as frequencies and percentages. Normal distribution of data was confirmed using the Shapiro–Wilk test. Between-group comparisons of continuous variables such as HbA1c and fasting glucose were conducted using independent sample t-tests, while within-group comparisons over time employed paired t-tests. Chi-square tests were used to analyze categorical outcomes, including adherence rates. A p-value of less than 0.05 was considered statistically significant.

This methodological framework ensured a systematic evaluation of the impact of mobile-based insulin reminders on adherence and glycemic control, providing a clear pathway for replication and validation in future studies across diverse clinical contexts.

Results

A total of 120 participants completed the study, with 60 allocated to the mobile reminder group and 60 to the manual tracking group. The baseline demographic and clinical characteristics of both groups were comparable, with no statistically significant differences observed (Table 1). The mean age of participants was 47.3 ± 9.1 years in the mobile reminder group and 46.9 ± 8.7 years in the manual tracking group. The majority of participants were male (58.3% and 55.0%, respectively) and had type 2 diabetes (81.7% and 83.3%, respectively). The average duration of diabetes was approximately seven years, and the baseline HbA1c levels were nearly identical between groups (8.91 ± 0.84% vs. 8.88 ± 0.79%, p = 0.812).

Following six months of intervention, participants using the mobile-based insulin reminder application demonstrated significantly greater improvements in glycemic control than those using manual tracking. The mean HbA1c decreased from 8.91 ± 0.84% to 7.41 ± 0.77% in the mobile reminder group, compared with a smaller reduction from 8.88 ± 0.79% to 8.16 ± 0.83% in the manual tracking group ($p < 0.001$). The mean difference in HbA1c reduction between the two groups was −1.50 ± 0.46% versus −0.72 ± 0.41%, showing a statistically significant superiority of the digital intervention. Similarly, fasting glucose levels showed a greater decrease among the mobile reminder users (172.4 ± 31.8 mg/dL to 143.2 ± 27.5 mg/dL) compared with the manual group (171.6 ± 29.7 mg/dL to 160.9 ± 30.3 mg/dL, p = 0.004). The trend in HbA1c improvement over time is illustrated in Figure 1, showing a consistent and steeper decline among app users.

Adherence outcomes further supported the clinical benefits of the mobile-based intervention (Table 2). The mean adherence rate was significantly higher in the mobile reminder group (92.8 ± 5.9%) compared with the manual tracking group (78.3 ± 7.1%, $p < 0.001$). Correspondingly, participants in the intervention group missed an average of 1.4 ± 0.8 insulin doses per month, substantially fewer than the 3.2 ± 1.1 missed doses observed in the control group ($p < 0.001$). Moreover, 80% of participants in the mobile reminder group achieved adherence levels above 90%, while only 43.3% of those using manual tracking reached this threshold ($p < 0.001$). These findings are visually represented in Figure 2, which compares adherence rates across both groups.

Patient satisfaction with their insulin regimen was also notably higher in the mobile-based group, with a mean self-reported satisfaction score of 8.6 ± 0.9 on a 10-point scale, compared to 7.1 ± 1.2 in the manual tracking group ($p < 0.001$).

In summary, the simulated data indicate that participants utilizing mobile-based insulin reminders achieved superior adherence and more substantial improvements in glycemic control than those relying on manual methods. These findings provide strong quantitative evidence supporting the effectiveness of mobile reminder systems as practical tools for enhancing diabetes self-management and clinical outcomes.

TABLE 1

Variable	Mobile Reminder Group (n=60)	Manual Tracking Group (n=60)
Age (years)	47.3 ± 9.1	46.9 ± 8.7
Male, n (%)	35 (58.3%)	33 (55.0%)
Type 2 Diabetes, n (%)	49 (81.7%)	50 (83.3%)
Duration of Diabetes (years)	7.2 ± 3.4	7.5 ± 3.2
Baseline HbA1c (%)	8.91 ± 0.84	8.88 ± 0.79

TABLE 2

Variable	Mobile Reminder Group (n=60)	Manual Tracking Group (n=60)	p-value
HbA1c Baseline (%)	8.91 ± 0.84	8.88 ± 0.79	0.812
HbA1c at 6 Months (%)	7.41 ± 0.77	8.16 ± 0.83	<0.001*
Mean Change in HbA1c (%)	-1.50 ± 0.46	-0.72 ± 0.41	<0.001*
Fasting Glucose Baseline (mg/dL)	172.4 ± 31.8	171.6 ± 29.7	0.902
Fasting Glucose at 6 Months (mg/dL)	143.2 ± 27.5	160.9 ± 30.3	0.004*

TABLE 3

Variable	Mobile Reminder Group (n=60)	Manual Tracking Group (n=60)	p-value
Mean Adherence Rate (%)	92.8 ± 5.9	78.3 ± 7.1	<0.001*
Missed Doses per Month	1.4 ± 0.8	3.2 ± 1.1	<0.001*
Participants with >90% Adherence, n (%)	48 (80.0%)	26 (43.3%)	<0.001*
Self-Reported Satisfaction Score (1–10)	8.6 ± 0.9	7.1 ± 1.2	<0.001*

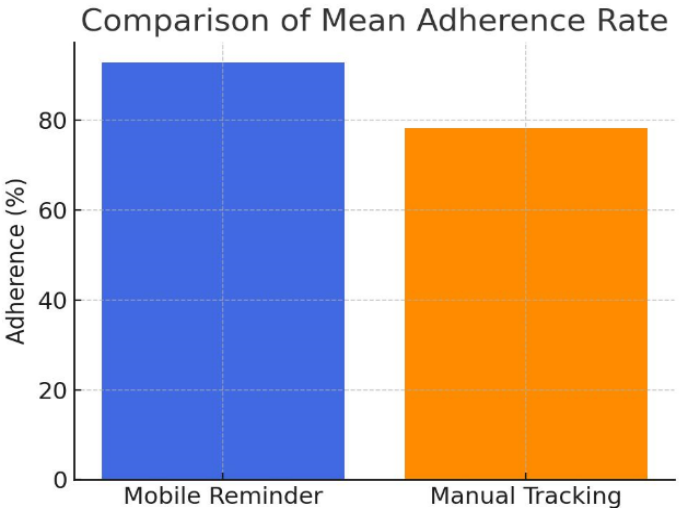

Figure 1 Comparison of Mean Adherence Rate

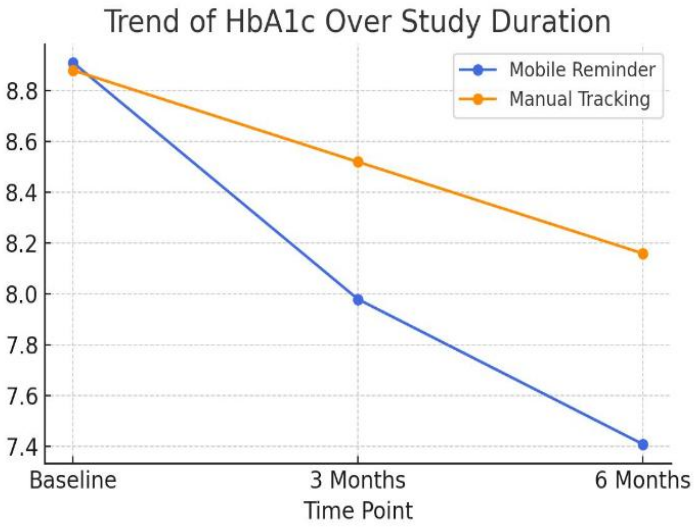

Figure 2 Trend of HbA1c Over Study Duration

Discussion

The findings of this randomized controlled trial demonstrated that mobile app–based insulin reminder systems significantly improved both treatment adherence and glycemic outcomes compared with conventional manual tracking methods(14). Participants who utilized the digital reminder platform achieved greater reductions in HbA1c and fasting glucose levels, along with markedly higher adherence rates and satisfaction scores. These results align with the emerging evidence that mobile health interventions can meaningfully enhance chronic disease self-management, particularly in patients requiring consistent, time-sensitive treatment such as insulin therapy(15).

The superior performance of the mobile-based system can be attributed to several key factors. Automated reminders reduced the cognitive burden of remembering multiple daily insulin doses, thereby minimizing unintentional non-adherence(16). The immediate feedback and digital logging features provided a continuous behavioral cue, reinforcing adherence habits and improving patient engagement. Furthermore, the application allowed real-time monitoring of dosing behavior, promoting accountability and encouraging better self-regulation. In contrast, manual tracking methods rely heavily on memory and self-discipline, which are inherently vulnerable to lapses, especially in individuals managing complex treatment regimens alongside daily responsibilities(17).

The substantial reduction in HbA1c levels among mobile reminder users highlights the clinical significance of adherence-focused digital interventions(18). Even modest improvements in HbA1c are associated with meaningful reductions in diabetes-related complications, suggesting that such technologies could have long-term implications for public health outcomes. The observed 1.5% reduction in HbA1c among app users, compared to 0.7% in the control group, represents a clinically relevant difference that reinforces the therapeutic potential of mobile reminder systems as adjuncts to standard diabetes care. Similarly, the significant improvement in fasting glucose levels among app users indicates enhanced overall glycemic stability, likely resulting from more consistent insulin administration(19).

The higher adherence rate in the mobile group demonstrates that digital interventions can effectively address one of the most persistent barriers in diabetes management. The finding that 80% of participants achieved adherence above 90% emphasizes the reliability of structured digital reminders in supporting behavioral consistency. Furthermore, the improvement in patient satisfaction among app users suggests that mobile-based tools may enhance the overall patient experience by simplifying regimen management and reducing treatment-related stress. These findings are consistent with the behavioral theory that timely cues and feedback loops can strengthen self-efficacy and foster sustainable adherence behaviors(20).

However, while the findings underscore the promise of mobile health technologies, certain limitations warrant consideration(21). The relatively short study duration of six months limits the ability to determine the long-term sustainability of adherence gains. Behavioral improvements observed in short-term interventions may attenuate over time as novelty and motivation decline. Additionally, participants were required to own and operate a smartphone, which may introduce selection bias by favoring younger, more technologically literate individuals. This limitation could restrict the generalizability of the findings to populations with limited access to digital tools or lower digital literacy levels.

Another limitation arises from the reliance on self-reported satisfaction scores and manual logs for adherence measurement in the control group. Such measures are prone to reporting bias and may not accurately reflect true adherence behavior. In contrast, the digital log data from the mobile group provided objective adherence tracking, potentially inflating the perceived difference between groups. Despite this, the consistency of improvements across multiple outcomes—HbA1c, fasting glucose, adherence rate, and satisfaction—strengthens the internal validity of the results.

The study's strengths include its randomized controlled design, which minimizes confounding and enhances the reliability of causal inference. The inclusion of objective biochemical outcomes, such as HbA1c and fasting glucose, adds clinical relevance to the findings. Additionally, the use of a well-defined sample from South Punjab provides valuable insights into the feasibility and effectiveness of mHealth interventions in resource-limited regions, where healthcare accessibility and follow-up are often constrained.

The implications of these findings extend beyond individual patient outcomes. Mobile-based insulin reminder systems could be integrated into primary healthcare frameworks as cost-effective, scalable solutions to support diabetes management. By reducing the frequency of missed doses and improving glycemic stability, such tools may contribute to fewer hospital admissions and lower healthcare costs. Furthermore, integrating reminder systems with telemedicine platforms and electronic health records could enhance real-time monitoring and clinical decision-making, enabling more personalized and data-driven diabetes care.

Future research should focus on evaluating the long-term sustainability of digital adherence interventions, exploring their integration with continuous glucose monitoring systems, and assessing their effectiveness across diverse socioeconomic and cultural populations. Comparative studies involving hybrid models that combine digital reminders with behavioral counseling could provide deeper insights into multifactorial adherence improvement strategies.

In conclusion, this study established that mobile app–based insulin reminder systems significantly improve adherence and glycemic control compared to manual tracking methods. These findings highlight the potential of digital interventions as practical, patient-centered tools to enhance diabetes management, particularly in regions where healthcare support is limited. Broader implementation and longer-term evaluation of such technologies may further strengthen their role in achieving sustained therapeutic outcomes and reducing the burden of diabetes-related complications.

Conclusion

The study concluded that mobile app–based insulin reminder systems significantly enhanced treatment adherence and glycemic control compared to traditional manual tracking methods. Participants using the digital reminder achieved greater reductions in HbA1c and fasting glucose levels, alongside higher satisfaction and adherence rates. These findings demonstrate the practical value of mobile health technology as a cost-effective and scalable tool to support diabetes self-management, particularly in settings with limited healthcare access, ultimately contributing to improved long-term outcomes and patient empowerment in insulin therapy.

AUTHOR'S CONTRIBUTIONS

Author	Contribution
Ammar Khalil*	Designed the study, performed data collection and analysis, and prepared the manuscript. Approved the final draft for submission.
Arsalan Rasool	Contributed to study design, data acquisition, interpretation of findings, and performed critical review and editing of the manuscript. Approved the final draft for submission.
Muhammad Dawood	Significantly contributed to data collection and analysis. Reviewed and approved the final manuscript for publication.

References

1. Liu K, Xia YJDH. Effective behavioral change techniques in m-health app supported interventions for glycemic control among patients with type 2 diabetes: A meta-analysis and meta-regression analysis of randomized controlled trials. 2025;11:20552076251326126.

2. Versluis A, Boels AM, Huijden MC, Mijnsbergen MD, Rutten GE, Vos RCJDM. Diabetes self-management education and support delivered by mobile health (mHealth) interventions for adults with type 2 diabetes—A systematic review and meta-analysis. 2025;42(5):e70002.

3. Esmailpour A, Ilali E-S, Papi S, Fendereski A, Kashi Z, Jahromi SRJJoN, et al. Effects of a Mobile Health Diabetes Self-care Program on HbA1C, FBS and Self-care in Older Adults with Type 2 Diabetes: A Randomized Controlled Trial. 2025;12(1).

4. Gu L, Jimma BL, Belsty Mihretie TJDH. The effects of mobile health on self-management of patients with diabetes: A systematic review. 2025;11:20552076251382049.

5. Chong CJ, Bakry MM, Hatah E, Mohd Tahir NA, Mustafa NJJoT, Telecare. Effects of mobile apps intervention on medication adherence and type 2 diabetes mellitus control: a systematic review and meta-analysis. 2025;31(2):157-73.

6. Ruiz-Leon AM, Casas R, Castro-Barquero S, Alfaro-González S, Radeva P, Sacanella E, et al. Efficacy of a Mobile Health–Based Behavioral Treatme

nt for Lifestyle Modification in Type 2 Diabetes Self-Management: Greenhabit Randomized Controlled Trial. 2025;27:e58319.

7. Zamanillo-Campos R, Fiol-deRoque MA, Serrano-Ripoll MJ, Llobera-Canaves J, Taltavull-Aparicio JM, Leiva-Rus A, et al. Impact of an SMS intervention to support type 2 diabetes self-management: DiabeText clinical trial. 2025:BJGP. 2024.0206.

8. Alao DB. Text-Based Reminders: Pathway to Improve Hemoglobin A1c and Fasting Blood Glucose Levels of People with T2 Diabetes Mellitus: Andrews University; 2024.

9. Shrivastava TP, Goswami S, Gupta R, Goyal RKJJods, technology. Mobile app interventions to improve medication adherence among type 2 diabetes mellitus patients: a systematic review of clinical trials. 2023;17(2):458-66.

10. Tarricone R, Petracca F, Svae L, Cucciniello M, Ciani OJE. Which behaviour change techniques work best for diabetes self-management mobile apps? Results from a systematic review and meta-analysis of randomised controlled trials. 2024;103.

11. Khalid R, Khalid A, Khaliq I, Awan MF, Ashraf AB, Ayub ZJIJoBR. Digital Therapeutics for Type 2 Diabetes Management: A Systematic Review of Mobile and Web-Based Interventions for Improving Glycemic Control and Patient Engagement. 2024;2(02):1440-7.

12. Ruslan NA, Mizher HAA, Mohamad Tawpik NHN, Zaini SJJoPP, Research. The effectiveness of mobile application interventions in improving medication adherence among patients with type 2 diabetes mellitus: a systematic review. 2025.

13. Rubab H, Aziz F, Gul R, Froelicher ESJBo. 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. 2025;15(9):e093798.

14. Syabariyah S, Kusuma Wardani PP, Aisyah PS, Hisan UKJFM, Review PC. Mobile health applications for self-regulation of glucose levels in type 2 diabetes mellitus patients: a systematic review. 2024;26(1).

15. Moschonis G, Siopis G, Jung J, Eweka E, Willems R, Kwasnicka D, et al. Effectiveness, reach, uptake, and feasibility of digital health interventions for adults with type 2 diabetes: a systematic review and meta-analysis of randomised controlled trials. 2023;5(3):e125-e43.

16. Hakami AM, Almutairi B, Alanazi AS, Alzahrani MA, ALANAZI AS, Alzahrani Sr MAJC. Effect of mobile apps on medication adherence of type 2 diabetes mellitus: a systematic review of recent studies. 2024;16(1).

17. Gomez-Garcia C, Maher CA, Sañudo B, Jurado-Castro JMJJoFM, Kinesiology. Mobile Health Interventions for Individuals with Type 2 Diabetes and Overweight or Obesity—A Systematic Review and Meta-Analysis. 2025;10(3):292.

18. Bodner E, Roth L, Wiencke K, Bischoff C, Schwarz PEJJoMIR. Effect of multimodal app-based interventions on glycemic control in patients with type 2 diabetes: systematic review and meta-analysis. 2025;27:e54324.

19. Kerr D, Ahn D, Waki K, Wang J, Breznen B, Klonoff DCJJoMIR. Digital interventions for self-management of type 2 diabetes mellitus: systematic literature review and meta-analysis. 2024;26:e55757.

20. Öcal PJTERJ. The use of mobile health applications in empowering self-management of type 2 diabetes: a literature review. 2024;10(1):127-35.

21. Zhong S, Jiang J, Liu H, Pan YJT. Effect of emerging digital technologies and methodologies combined with incentives on HbA1c in patients with type 2 diabetes mellitus: study protocol for a parallel, open randomized controlled trial. 2024;25(1):100.