ORIGINAL ARTICLE

Smartphone-based drug reminder app intervention to improve adherence in elderly diabetic patients: A community pilot study

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Abstract

Background: Medication non-adherence it is a major issue in the management of diabetes in older adults, it will lead poor blood sugar control and there is a higher chance of developing complications. Digital health interventions show a potential for improving medication adherence in elderly patients with type 2 diabetes mellitus. **Objective:** The study investigated whether a smartphone-based medication reminder application could enhance medication adherence, glycemic control and health outcomes in elderly patients with type 2 diabetes mellitus in a community setting. **Materials and Methods:** A 6-month prospective randomized controlled trial was conducted with 120 elderly diabetic patients (aged ≥65 years) recruited from three community health centers. Participants were randomly assigned to either the intervention group (n = 60), which received a customized smartphone medication reminder app with daily alerts and educational content, or the control group (n = 60), which received standard care. Primary outcomes included medication adherence (measured by the Morisky Medication Adherence Scale-8), glycated hemoglobin (HbA1c), fasting blood glucose (FBG), and postprandial blood glucose (PPBG). Secondary outcomes included blood pressure (BP), lipid profile, quality of life, diabetes self-management behaviors, and app usability. Assessments are conducted at baseline, 3–6 months. **Results:** Medication adherence scores received a higher ratingin the intervention group than in the control group at both 3 months (7.2 ± 0.8 vs. 5.6 ± 1.2, $P < 0.001$) and t the 6-month follow-up, participants in the intervention group experienced significant reductions in HbA1c (7.1% vs. 8.0%), FBG (126.4 mg/dL vs. 156.2 mg/dL) and PPBG (168.2 mg/dL vs. 209.8 mg/dL).The intervention group also achieved better BP control, improved lipid profiles, higher quality of life and greater satisfaction with managing their diabetes. A large majority of participants (82.3%) expressed a positive feedback about the app's ease of use. **Conclusion:** The use of a smartphone-based medication reminder application led to substantial improvements in medication adherence and glycemic control among elderly diabetic individuals. This intervention is a practical, well-received and successful method for helping older adults manage their diabetes. Future studies should explore how to maintain the benefits and adapt the intervention to different healthcare environments.

Key words: Diabetes mellitus, digital intervention, elderly, medication adherence, mobile health, reminder systems

INTRODUCTION

Diabetes mellitus is characterized by elevated blood glucose levels caused by intrinsic problems with producing or using insulin. Diabetes incidence is on the rise, particularly among seniors around the world. Based on data provided by the International Diabetes Federation, nearly 537 million adults living worldwide had diabetes in 2021. By the year 2030, diabetes is set to

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affect 643 million people and by 2045, the number might reach 783 million.[1-3] A large number of these individuals are age 65 and older, making them especially vulnerable in handling their diabetic condition. Guaranteeing that patients take their medications as directed can significantly help manage diabetes.[3,4] Still, non-adherence in older adults with diabetes can vary significantly between 36% and 87%, often caused by complicated medication regimens, taking numerous drugs, mental impairment, poor health understanding, economic difficulties, fear of side effects, and forgetfulness. Non-adherence may result in worse blood sugar control, increased risk of complications, more hospitalizations, greater medical costs and a lower standard of living, all of which are typically exacerbated by the presence of other health problems and aging.[5-7] Improving adherence in the elderly with diabetes can help alleviate these problems. Educational programs, pill organizers, calendars, and written directions can be helpful but do not always work effectively. Still, increased adoption of smartphones by older adults makes mHealth solutions promising. They help remind users to take their medications, track adherence, offer instructional materials, connect them with healthcare professionals, and motivate healthy behaviours.[8-10]

Researchers have begun examining how mobile apps can help individuals with chronic illnesses, including diabetes, improve their medication taking habits. A recent systematic review showed that electronic health (mHealth) interventions can bring about minor gains in medication adherence among people with chronic illnesses. Nonetheless, there is a scarcity of evaluations focusing solely on older adults with diabetes, which are frequently constrained by small participant numbers, short study periods and incomplete measures of effectiveness. A key problem in applying mHealth technology to seniors is that they may struggle with certain aspects such as digital literacy, comfort with new technologies, physical impairments, and cognitive differences.[11-13] The current study investigates the impact of a smartphone medication reminder app created for older patients with diabetes in the community. The tool was designed using input from both older adults and health experts to maximize both its usefulness and clinical relevance.[14] A 6-month, two-group study involving comprehensive outcome measures was undertaken to evaluate how well the app improved medication adherence and patient well-being in this high-risk group.[15]

Aim and Objectives

Aim

The study aims to assess smartphone-based medication reminder app how it will help elderly patients with type 2 diabetes adhere to their medication regimen and manage their blood sugar levels in the community.

Objectives

1. The study aimed to evaluate the effect of the smartphone-based medication reminder application on medication adherence using the Morisky medication adherence scale-8 (MMAS-8)
2. To evaluate changes in glycemic control parameters (glycated hemoglobin [HbA1c], fasting blood glucose [FBG], and postprandial blood glucose [PPBG]) following the intervention
3. To determine the effects of the intervention on secondary clinical outcomes, including blood pressure (BP) and lipid profile
4. To assess the impact of the intervention on diabetes self-management behaviors and quality of life
5. To explore the relationship between medication adherence, glycemic control, and other health outcomes in the context of the digital intervention.

MATERIALS AND METHODS

Study Period and Study Design

A 6 month prospective, randomized controlled trial using a parallel-group design (1:1 ratio) compared a smartphone-based medication reminder app plus standard care (intervention group) with standard care alone (control group). Assessments were conducted at baseline, 3 months, and 6 months.

Study Setting

Conducted at three urban community health centers selected for their large elderly diabetic population, electronic health record systems, and willingness to participate.

Study Population

Study population of 120 elderly diabetic patients (aged ≥65 years) recruited from three community health centers.

Study Criteria

Inclusion criteria

- Age ≥65 years
- Type 2 diabetes duration >12 months
- On ≥2 oral hypoglycemic agents
- HbA1c ≥7.0% at screening
- Able to use a smartphone independently or with assistance
- Able to read/comprehend English or the local language
- Provided informed consent.

Exclusion criteria

- Mini-mental state exam score <24
- Visual/motor impairments limiting smartphone use
- Insulin-dependent diabetes
- Recent severe hypoglycemia (past 3 months)
- Life expectancy <1 year
- Enrolled in another intervention study
- Planning to relocate before study completion.

Sample Size Calculation

Based on a 1.0-point expected difference in MMAS-8 scores (standard deviation [SD] 1.5), with 90% power and $\alpha = 0.05$, 48 participants per group were needed. With 20% anticipated dropout, 120 participants (60/group) were targeted.

Recruitment and Randomization

Participants are identified via electronic records and approached in person or by phone. After consent, they were randomized using a computer-generated block randomization (block size 4), stratified by site. Allocation was concealed using sequentially numbered, opaque, sealed envelopes opened by an independent research assistant.

Intervention

Development of the smartphone application

The "Diabetes Med Alert" app was designed with input from elderly diabetic patients, endocrinologists, diabetic educators, pharmacists, and software developers. The application was revised several times after testing with elderly users to make it accessible to those with different levels of technical skills.

Features of the smartphone application

The Diabetes MedAlert application included the following key features:

- The app provides features aimed at helping senior diabetic individuals control their health and diabetes. Users can personalize medication alerts using sounds, vibrations or visual cues as well as maintain a record of when they take the medication and why they could not take it at certain times
- Every medication is described in detail, including its purpose, dosage, potential side effects, and any special circumstances
- The system shows real-time blood sugar levels and offers visual aids to help users understand their glucose trends
- The app provides brief educational resources on how to manage diabetes, take medications properly and live a healthy life
- Users have the option to generate weekly reports that include both medication adherence and glucose data to discuss with their healthcare providers.

Intervention Protocol

Each participant received a one-on-one training session from a trained research assistant that lasted 60 min. The assistant guided users in installing the app, setting up an account, entering all medication information, configuring reminders and learning to use all the app's features. Employers were required to provide all information about their prescribed diabetes medications during the initial session. Regular phone calls were made weekly throughout the study to help participants with technical issues and to remind them to keep using the application. A support line was available for all participants should they need help resolving technical problems with the application during the study. As always, the participants continued to receive regular care from their healthcare provider(s).

Control Group

Partakers in the control group received:

1. Standard care: The normality group received the typical care for diabetes from their healthcare providers in the form of scheduled appointments, basic medication guidance's and handwritten materials describing self-care behaviours for diabetes patients
2. Attention control: Phone calls every 4 weeks for the first 4 months (at weeks 1, 2, 4 and 8) that ask generic questions about health and diabetes management to eliminate any influence from potentially increased attention on the participants in the interventions.[16]

Outcome Measures

Primary outcomes

1. Medication adherence: Assessed using the validated 8-item MMAS-8, with scores ranging from 0 to 8 (higher scores indicating better adherence). Adherence was categorized as low (<6), medium (6–<8), or high (8).
2. Glycemic control:
   - HbA1c
   - FBG
   - 2-h PPBG.

Secondary outcomes

1. Clinical parameters:
   - BP (systolic and diastolic)
   - Lipid profile (total cholesterol, low-density lipoprotein [LDL]-cholesterol, high-density lipoprotein [HDL]-cholesterol, triglycerides)
   - Body mass index (BMI).

2. Diabetes self-management: Assessed using the diabetes self-management questionnaire (DSMQ), which evaluates glucose management, dietary control, physical activity, and healthcare use
3. Quality of life: Measured using the diabetes quality of life brief clinical inventory (DQOL-BCI)

4. Diabetes-related knowledge: Evaluated using the diabetes knowledge questionnaire (DKQ)
5. Diabetes-related distress: Assessed using the problem areas in diabetes scale (PAID-5)
6. Application usage: Collected through backend data, including frequency of app opening, duration of use, feature utilization, and response to medication reminders
7. User satisfaction and usability: Evaluated using the system usability scale (SUS) and a custom-developed satisfaction questionnaire
8. Healthcare utilization: Number of emergency department visits, hospitalizations, and unscheduled clinic visits related to diabetes.

Data Collection

Data collection was performed at baseline, 3 months, and 6 months by trained research assistants blinded to group allocation. The following procedures were implemented:

1. Questionnaires: Self-reported measures were administered through in-person interviews at the community health centers
2. Blood sampling: Blood samples for HbA1c and lipid profile were collected after overnight fasting at the laboratory facilities of each participating health center
3. Blood glucose measurements: FBG was measured after an overnight fast (at least 8 h), and PPBG was measured 2 h after a standardized meal
4. BP measurement: Three consecutive readings were taken using calibrated automatic BP monitors after 5 min of rest, with the mean of the second and third readings recorded
5. Anthropometric measurements: Height and weight were measured using standardized procedures, and BMI was calculated
6. Application usage data: Automatically collected through the application's backend analytics system for participants in the intervention group
7. Healthcare utilization: Obtained from patient self-reports and verified through electronic health records when available.

Data Analysis

Statistical analysis was conducted using Statistical Package for the Social Sciences, version 26.0 (IBM Corp., Armonk, NY), with a significance threshold set at $P < 0.05$. Descriptive statistics summarized baseline data, using means and SDs for continuous variables, and frequencies with percentages for categorical ones. To compare groups, independent *t*-tests or Mann-Whitney U tests were applied for continuous data depending on distribution, while Chi-square or Fisher's exact tests were used for categorical comparisons. Within-group changes from baseline to follow-up were assessed using paired t-tests or Wilcoxon signed-rank tests. Mixed-effects models analyzed outcome changes over time, accounting for missing data and adjusting for relevant covariates. Subgroup analyses were pre-planned based on age (65–74 vs. ≥75 years), initial HbA1c levels (<8% vs. ≥8%), and baseline medication adherence (low vs. medium/high). Correlations between medication adherence, glycemic control, app usage, and other outcomes were evaluated using Pearson or Spearman coefficients. Multivariable analyses, including linear and logistic regression, identified predictors of changes in adherence and glycemic control while adjusting for confounding variables. Missing data were handled using multiple imputation methods, and sensitivity analyses compared these results to complete case analyses.

Ethical Considerations

The present study was approved by institutional review board.

RESULTS

Participant Flow and Baseline Characteristics

In Table1, a total of 120 eligible participants were randomly assigned to either the intervention or control group. At the 6 month mark, 53 participants in the intervention group and 51 in the control group had finished the study. Some participants dropped out because of health problems, moving away, lack of motivation, or technical difficulties [Table 1].

The intervention and control groups were similar in age at the start of the study, with means of 72.4 and 71.8 years, respectively. The intervention and control groups were matched in terms of demographics, clinical characteristics and there were no significant differences between them in glycemic control, BP, adherence, self-care, or quality of life.

Medication Adherence

The quality of adherence to MMAS-8 improved by 1.8 points from the start to 3 months in the intervention group, compared to <0.3 in the control. Both follow-ups saw significant differences among the groups ($P < 0.001$) [Table 2].

Table 3, shows the intervention group experienced significant improvement in medication adherence, with high adherence increasing from 6.7% to 67.9% during the 6-month period. The control group experienced only a small rise in low adherence which increased from 56.7% to 60.8% [Table 3].

Glycemic Control

Table 4 shows significant improvements in glycemic control in the intervention group, with HbA1c dropping from 8.3% to 7.1%, whereas the control group saw minimal change. Fasting and postprandial glucose levels also improved notably in the intervention group at both 3 and 6 months ($P < 0.001$).

Table 1: Baseline demographic and clinical characteristics of study participants

Characteristic	Intervention group (*n*=60)	Control group (*n*=60)	*P*-value
Age (years), mean±SD	72.4±5.3	71.8±5.7	0.542
Gender, *n* (%)			0.714
Male	32 (53.3)	30 (50.0)	
Female	28 (46.7)	30 (50.0)	
Education level, *n* (%)			0.826
Primary or less	13 (21.7)	15 (25.0)	
Secondary	28 (46.7)	26 (43.3)	
College or higher	19 (31.7)	19 (31.7)	
Duration of diabetes (years), mean±SD	12.6±7.2	11.9±6.8	0.587
Number of diabetic medications, mean±SD	2.8±0.7	2.7±0.8	0.471
Total number of medications, mean±SD	5.9±2.3	5.7±2.1	0.621
Comorbidities, *n* (%)			
Hypertension	45 (75.0)	42 (70.0)	0.541
Dyslipidemia	38 (63.3)	40 (66.7)	0.701
Coronary artery disease	15 (25.0)	13 (21.7)	0.668
Chronic kidney disease	10 (16.7)	8 (13.3)	0.607
Diabetic retinopathy	12 (20.0)	11 (18.3)	0.818
Diabetic neuropathy	18 (30.0)	16 (26.7)	0.684
BMI (kg/m^2), mean±SD	28.6±4.3	29.1±4.5	0.523
HbA1c (%), mean±SD	8.3±1.1	8.2±1.0	0.608
Fasting blood glucose (mg/dL), mean±SD	162.7±28.4	158.9±26.8	0.457
Postprandial blood glucose (mg/dL), mean±SD	211.5±34.6	208.3±32.1	0.602
Systolic BP (mmHg), mean±SD	143.2±12.6	141.8±13.2	0.549
Diastolic BP (mmHg), mean±SD	82.4±8.3	81.9±7.8	0.731
MMAS-8 score, mean±SD	5.4±1.2	5.5±1.3	0.655
Medication adherence category, *n* (%)			0.928
Low (<6)	35 (58.3)	34 (56.7)	
Medium (6–<8)	21 (35.0)	22 (36.7)	
High (8)	4 (6.7)	4 (6.7)	
Smartphone experience (years), mean±SD	3.6±2.1	3.4±2.3	0.618
DSMQ score, mean±SD	5.8±1.4	5.7±1.3	0.681
DQOL-BCI score, mean±SD	62.4±12.8	63.1±13.2	0.764

SD: Standard deviation, BMI: Body mass index, BP: Blood pressure, MMAS-8: Morisky medication adherence scale-8, DSMQ: Diabetes self-management questionnaire, DQOL-BCI: Diabetes quality of life brief clinical inventory, HbA1c: Glycated hemoglobin

Table 2: Changes in medication adherence (MMAS-8 scores) over the study period

Time point	Intervention group	Control group	Mean difference (95% CI)	*P*-value
Baseline	5.4±1.2	5.5±1.3	−0.1 (−0.5–0.3)	0.655
3 months	7.2±0.8	5.6±1.2	1.6 (1.2–2.0)	<0.001
6 months	7.8±0.6	5.4±1.3	2.4 (2.0–2.8)	<0.001
Change from baseline to 3 months	1.8±0.6	0.1±0.4	1.7 (1.5–1.9)	<0.001
Change from baseline to 6 months	2.4±0.8	−0.1±0.5	2.5 (2.2–2.8)	<0.001
P-value (within-group change at 6 months)	<0.001	0.183		

Values are presented as mean±standard deviation. MMAS-8: Morisky medication adherence scale-8, CI: Confidence interval

Table 3: Changes in medication adherence categories over the study period

Adherence category	Intervention group			Control group			*P*-value*
	Baseline (*n*=60)	3 months (*n*=56)	6 months (*n*=53)	Baseline (*n*=60)	3 months (*n*=54)	6 months (*n*=51)	
Low (<6), *n* (%)	35 (58.3)	8 (14.3)	3 (5.7)	34 (56.7)	32 (59.3)	31 (60.8)	<0.001
Medium (6–<8), *n* (%)	21 (35.0)	32 (57.1)	14 (26.4)	22 (36.7)	19 (35.2)	17 (33.3)	<0.001
High (8), *n* (%)	4 (6.7)	16 (28.6)	36 (67.9)	4 (6.7)	3 (5.6)	3 (5.9)	<0.001

P-value for between-group comparison at 6 months using Chi-square test, *$P < 0.001$ Very highly significant

Table 4: Changes in glycemic parameters over the study period

Parameter	Time point	Intervention group	Control group	Mean difference (95% CI)	*P*-value
HbA1c (%)	Baseline	8.3±1.1	8.2±1.0	0.1 (−0.3–0.5)	0.608
	3 months	7.6±0.8	8.1±0.9	−0.5 (−0.8–−0.2)	0.002
	6 months	7.1±0.6	8.0±0.9	−0.9 (−1.2–−0.6)	<0.001
	Change (baseline to 6 months)	−1.2±0.7	−0.2±0.4	−1.0 (−1.3–−0.7)	<0.001
Fasting blood glucose (mg/dL)	Baseline	162.7±28.4	158.9±26.8	3.8 (−5.8–13.4)	0.457
	3 months	142.3±20.6	155.4±25.1	−13.1 (−21.9–−4.3)	0.003
	6 months	126.4±18.2	156.2±24.6	−29.8 (−38.1–−21.5)	<0.001
	Change (baseline to 6 months)	-36.3±19.8	−2.7±11.4	−33.6 (−40.2–−27.0)	<0.001
Postprandial blood glucose (mg/dL)	Baseline	211.5±34.6	208.3±32.1	3.2 (−8.7–15.1)	0.602
	3 months	184.6±26.2	205.8±30.4	−21.2 (−32.0–−10.4)	<0.001
	6 months	168.2±22.4	209.8±31.2	−41.6 (−52.1–−31.1)	<0.001
	Change (baseline to 6 months)	−43.3±23.6	1.5±14.8	−44.8 (−52.8–−36.8)	<0.001

Values are presented as mean±standard deviation. CI: Confidence interval, HbA1c: Glycated hemoglobin

Table 5: Proportion of participants achieving glycemic targets at baseline and 6 months

Target	Intervention group		Control group		*P*-value*
	Baseline (*n*=60)	6 months (*n*=53)	Baseline (*n*=60)	6 months (*n*=51)	
HbA1c <7.0%, *n* (%)	5 (8.3)	34 (64.2)	6 (10.0)	9 (17.6)	<0.001
Fasting blood glucose <130 mg/dL, *n* (%)	8 (13.3)	31 (58.5)	7 (11.7)	10 (19.6)	<0.001
Postprandial blood glucose <180 mg/dL, *n* (%)	10 (16.7)	37 (69.8)	9 (15.0)	8 (15.7)	<0.001
All three targets achieved, *n* (%)	2 (3.3)	25 (47.2)	3 (5.0)	4 (7.8)	<0.001

P-value for between-group comparison at 6 months using Chi-square test, *$P < 0.001$ Very highly significant. HbA1c: Glycated hemoglobin

As shown in Table 5, 64.2% of the intervention group reached the HbA1c target of <7.0% at 6 months, significantly higher than 17.6% in the control group ($P < 0.001$). The intervention group also had more participants meeting fasting and postprandial glucose targets.

Secondary Clinical Outcomes

BP

Table 6 shows a significant improvement in BP control in the intervention group, with systolic BP dropping from 143.2 to 132.1 mmHg, compared to a smaller reduction in the control group ($P < 0.001$). Diastolic BP also declined more in the intervention group than in the control group ($P = 0.003$).

Lipid Profile

Table 7 indicates that the intervention group experienced significant reductions in total cholesterol, LDL, and triglycerides, alongside an increase in HDL levels.

Diabetes Self-Management and Quality of Life

Diabetes self-management

Table 8 shows significant improvements in diabetes self-management behaviors in the intervention group, with DSMQ scores rising from 5.8 to 8.1 over 6 months, while the control group showed little change. All DSMQ subscales also improved significantly in the intervention group compared to controls ($P < 0.001$).

Table 6: Changes in blood pressure over the study period

Parameter	Time point	Intervention group	Control group	Mean difference (95% CI)	*P*-value
Systolic BP (mmHg)	Baseline	143.2±12.6	141.8±13.2	1.4 (−3.2–6.0)	0.549
	3 months	136.5±10.2	140.3±12.8	−3.8 (−7.9–0.3)	0.068
	6 months	132.1±8.7	138.4±11.5	−6.3 (−9.9–−2.7)	<0.001
	Change (baseline to 6 months)	−11.1±7.5	−3.4±5.6	−7.7 (−10.2–−5.2)	<0.001
Diastolic BP (mmHg)	Baseline	82.4±8.3	81.9±7.8	0.5 (−2.3–3.3)	0.731
	3 months	79.1±6.8	80.7±7.4	−1.6 (−4.1– 0.9)	0.210
	6 months	76.3±5.9	79.8±7.1	−3.5 (−5.9–−1.1)	0.004
	Change (baseline to 6 months)	−6.1±5.7	−2.1±4.2	−4.0 (−5.8–−2.2)	0.003

Values are presented as mean±standard deviation. BP: Blood pressure, CI: Confidence interval

Table 7: Changes in lipid profile over the study period

Parameter	Time point	Intervention group	Control group	Mean difference (95% CI)	*P*-value
Total cholesterol (mg/dL)	Baseline	189.6 ± 32.5	192.3 ± 34.2	−2.7 (−14.6–9.2)	0.653
	6 months	168.4 ± 26.8	188.7 ± 32.6	−20.3 (−31.5–−9.1)	<0.001
	Change (baseline to 6 months)	−21.2 ± 18.5	−3.6 ± 12.4	−17.6 (−23.7–−11.5)	<0.001
LDL-Cholesterol (mg/dL)	Baseline	112.8 ± 26.4	115.2 ± 27.8	−2.4 (−12.1–7.3)	0.622
	6 months	94.6 ± 21.7	112.5 ± 25.4	−17.9 (−26.6–−9.2)	<0.001
	Change (baseline to 6 months)	−18.2 ± 15.6	−2.7 ± 10.3	−15.5 (−20.4–−10.6)	<0.001
HDL-Cholesterol (mg/dL)	Baseline	42.5 ± 9.6	43.1 ± 10.2	−0.6 (−4.0–2.8)	0.731
	6 months	46.3 ± 8.9	43.8 ± 9.8	2.5 (−0.7–5.7)	0.125
	Change (baseline to 6 months)	3.8 ± 0.2	0.7 ± 3.1	3.1 (1.7–−4.5)	<0.001
Triglycerides (mg/dL)	Baseline	172.4 ± 68.3	168.9 ± 65.7	3.5 (−20.0–27.0)	0.769
	6 months	143.2 ± 52.6	162.4 ± 61.8	−19.2 (−40.1–1.7)	0.072
	Change (baseline to 6 months)	−29.2 ± 32.6	−6.5 ± 24.8	−22.7 (−33.6–−11.8)	<0.001

Values are presented as mean ± standard deviation. CI: Confidence interval, LDL: Low-density lipoprotein, HDL: High-density lipoprotein

Table 8: Changes in diabetes self-management questionnaire scores

Parameter	Time point	Intervention group	Control group	Mean difference (95% CI)	*P*-value
Total DSMQ score	Baseline	5.8±1.4	5.7±1.3	0.1 (−0.4–0.6)	0.681
	3 months	7.3±1.1	5.8±1.4	1.5 (1.0–2.0)	<0.001
	6 months	8.1±0.9	5.9±1.4	2.2 (1.7–2.7)	<0.001
	Change (baseline to 6 months)	2.3±1.2	0.2±0.6	2.1 (1.7–2.5)	<0.001
Glucose management	Baseline	5.6±1.6	5.5±1.5	0.1 (−0.5–0.7)	0.724
	6 months	8.3±1.0	5.7±1.6	2.6 (2.1–3.1)	<0.001
Dietary control	Baseline	5.4±1.8	5.3±1.7	0.1 (−0.5–0.7)	0.751
	6 months	7.8±1.2	5.5±1.8	2.3 (1.7–2.9)	<0.001
Physical activity	Baseline	5.2±1.9	5.1±1.8	0.1 (−0.6–0.8)	0.773
	6 months	7.5±1.4	5.3±1.9	2.2 (1.5–2.9)	<0.001
Healthcare use	Baseline	6.2±1.5	6.1±1.6	0.1 (−0.5–0.7)	0.736
	6 months	8.5±0.9	6.3±1.5	2.2 (1.7–2.7)	<0.001

Values are presented as mean±standard deviation. DSMQ: Diabetes self-management questionnaire, CI: Confidence interval

Quality of Life

Table 9 indicates a significant improvement in diabetes-related quality of life in the intervention group, with DQOL-BCI scores rising from 62.4 to 78.6 over 6 months, while the control group's scores remained nearly unchanged. The difference between groups was statistically significant ($P < 0.001$).

Diabetes-related Distress

Table 10 shows a significant reduction in diabetes-related distress in the intervention group, with PAID-5 scores dropping from 8.2 to 4.1 over 6 months, while the control group's scores stayed nearly the same. This between-group difference was statistically significant ($P < 0.001$).

Diabetes Knowledge

Table 11 demonstrates a significant increase in diabetes knowledge in the intervention group, with DKQ scores rising from 16.4 to 22.8 over 6 months, whereas the control group showed little change. The difference between groups was statistically significant ($P < 0.001$).

Healthcare Utilization

In Table 12, the intervention group had significantly fewer diabetes-related emergency visits ($P = 0.034$) and unscheduled clinic visits compared to the control group ($P = 0.008$).

Table 9: Changes in diabetes quality of life brief clinical inventory scores

Parameter	Time point	Intervention group	Control group	Mean difference (95% CI)	*P*-value
Total DQOL-BCI score	Baseline	62.4±12.8	63.1±13.2	−0.7 (−5.3–3.9)	0.764
	3 months	71.5±10.6	63.8±12.9	7.7 (3.4–12.0)	<0.001
	6 months	78.6±9.5	64.2±12.8	14.4 (10.1–18.7)	<0.001
	Change (baseline to 6 months)	16.2±9.8	1.1±5.4	15.1 (12.1–18.1)	<0.001
Satisfaction with treatment	Baseline	64.2±14.3	65.1±14.8	−0.9 (−6.0–4.2)	0.726
	6 months	82.5±10.2	66.3±14.5	16.2 (11.7–20.7)	<0.001
Impact of treatment	Baseline	60.8±13.5	61.5±14.1	−0.7 (−5.6–4.2)	0.783
	6 months	76.2±10.8	62.4±13.7	13.8 (9.2–18.4)	<0.001
Worry about future effects	Baseline	58.4±16.2	59.1±15.8	−0.7 (−6.5–5.1)	0.812
	6 months	72.8±12.5	60.3±15.2	12.5 (7.4–17.6)	<0.001

Values are presented as mean±standard deviation. DQOL-BCI: Diabetes quality of life brief clinical inventory, CI: Confidence interval

Table 10: Changes in PAID-5 scores

Parameter	Time point	Intervention group	Control group	Mean difference (95% CI)	*P*-value
PAID-5 score	Baseline	8.2±3.4	8.0±3.3	0.2 (−1.0–1.4)	0.743
	3 months	5.7±2.6	7.8±3.2	−2.1 (−3.2–−1.0)	<0.001
	6 months	4.1±2.2	7.6±3.1	−3.5 (−4.5–−2.5)	<0.001
	Change (baseline to 6 months)	−4.1±2.8	−0.4±1.2	−3.7 (−4.5–−2.9)	<0.001

Values are presented as mean±standard deviation. PAID-5: Problem areas in diabetes scale, CI: Confidence interval

Table 11: Changes in diabetes knowledge questionnaire scores

Parameter	Time point	Intervention group	Control group	Mean difference (95% CI)	*P*-value
DKQ score	Baseline	16.4±4.2	16.2±4.3	0.2 (−1.3–1.7)	0.794
	3 months	20.3±3.6	16.8±4.2	3.5 (2.1–4.9)	<0.001
	6 months	22.8±3.1	17.1±4.1	5.7 (4.3–7.1)	<0.001
	Change (baseline to 6 months)	6.4±3.5	0.9±1.8	5.5 (4.4–6.6)	<0.001

Values are presented as mean±standard deviation. DKQ: Diabetes knowledge questionnaire, CI: Confidence interval

Table 12: Healthcare utilization during the 6-month study

Parameter	Intervention group (*n*=53)	Control group (*n*=51)	*P*-value
Emergency department visits	3 (5.7)	10 (19.6)	0.034
Hospitalizations	1 (1.9)	5 (9.8)	0.102
Unscheduled clinic visits	8 (15.1)	19 (37.3)	0.008
Total healthcare encounters	12 (22.6)	34 (66.7)	<0.001

Values are presented as number of participants (percentage) with at least one healthcare encounter during the study

Application Usage and Usability

Application usage

In the intervention group, participants opened the app an average of 3.2 times daily in the 1st month, decreasing to 2.8 times by the 6th month, with a median session lasting 4.6 min. Most users (86.8%) responded to medication reminders within 30 min, 92.5% used the medication log, and 77.4% accessed educational content weekly [Table 13].

Application Usability and Satisfaction

The Diabetes Med Alert app received a high usability rating with a mean SUS score of 82.7 ± 8.9, reflecting excellent user experience. In addition, 82.3% of participants were highly satisfied, and 90.6% expressed intentions to keep using the app post-study [Table 14].

Factors Associated with Medication Adherence and Glycemic Control

Predictors of medication adherence improvement

Multiple linear regression in the intervention group showed that greater medication adherence improvement was significantly linked to more frequent app use, higher baseline HbA1c, and higher education level, while age, gender, diabetes duration, medication count, and comorbidities had no significant impact [Table 15].

Predictors of Glycemic Control Improvement

Multiple linear regression in the intervention group revealed that greater HbA1c reduction was significantly associated with improved medication adherence, higher baseline HbA1c, and more frequent app use, while age, gender, diabetes duration, and medication count showed no significant effect [Table 16].

Table 13: Application usage patterns in the intervention group (*n*=53)

Parameter	Value
Frequency of app opening (times/day)	
Month 1	3.2±1.4
Month 3	3.0±1.3
Month 6	2.8±1.2
Duration of app use (minutes/session)	
Month 1	5.8±2.3
Month 3	5.1±2.0
Month 6	4.6±1.8
Response to medication reminders	
Within 5 min, *n* (%)	24 (45.3)
Within 30 min, *n* (%)	22 (41.5)
Within 60 min, *n* (%)	5 (9.4)
>60 min or no response, *n* (%)	2 (3.8)
Feature utilization (at least once a week)	
Medication log, *n* (%)	49 (92.5)
Glucose monitoring, *n* (%)	46 (86.8)
Educational content, *n* (%)	41 (77.4)
Progress reports, *n* (%)	38 (71.7)
Communication with healthcare providers, i (%)	22 (41.5)

Values are presented as mean±standard deviation or number (percentage)

DISCUSSION

This randomized controlled trial shows that a smartphone-based medication reminder app significantly enhances medication adherence, glycemic control, and overall health outcomes in elderly patients with type 2 diabetes within a community setting.[17-19] The intervention group experienced a notable increase in medication adherence, reflected by a 2.4-point rise in the MMAS-8 score, while the control group showed minimal change.[20] This improved adherence led to meaningful reductions in HbA1c, FBG, and PPBG levels.[21-23] The degree of adherence improvement aligns with or surpasses results from earlier studies on digital health interventions for chronic diseases, such as mobile text messaging, which has been shown to double adherence odds. Our study stands out by showing long-term benefits in an older population, despite the challenges often faced in similar studies with shorter durations or participants who are less familiar with technology.[24-26] A 1.2% reduction in HbA1c is clinically meaningful and comparable to the effect of adding a second oral hypoglycemic agent. This improvement is in line with findings from major studies such as the UKPDS.[27,28] The intervention group also experienced significant reductions in both BP and lipid levels, suggesting that improved medication adherence also benefited the management of hypertension and dyslipidemia.[29,30]

Table 14: Application usability and satisfaction in the intervention group (***n***=53)

Parameter	Value
SUS score	82.7±8.9
Overall satisfaction, *n* (%)	
Very satisfied	28 (52.8)
Satisfied	16 (30.2)
Neutral	6 (11.3)
Dissatisfied	2 (3.8)
Very dissatisfied	1 (1.9)
Most helpful features (multiple selections allowed), *n* (%)	
Medication reminders	51 (96.2)
Medication log	43 (81.1)
Glucose monitoring	39 (73.6)
Educational content	32 (60.4)
Progress reports	28 (52.8)
Communication with healthcare providers	19 (35.8)
Would continue using the app after study completion, *n* (%)	
Definitely yes	31 (58.5)
Probably yes	17 (32.1)
Unsure	3 (5.7)
Probably no	1 (1.9)
Definitely no	1 (1.9)
Would recommend the app to others, *n* (%)	
Definitely yes	35 (66.0)
Probably yes	14 (26.4)
Unsure	3 (5.7)
Probably no	1 (1.9)
Definitely no	0 (0.0)

Values are presented as mean±standard deviation or number (percentage). SUS: System usability scale

Table 15: Multiple linear regression analysis of factors associated with medication adherence improvement in the intervention group

Variable	Standardized β coefficient	95% CI	*P*-value
Frequency of app use (times/day)	0.32	0.10–0.54	0.006
Baseline HbA1c (%)	0.28	0.06–0.50	0.014
Education level (per category increase)	0.25	0.03–0.47	0.029
Age (years)	−0.18	−0.40–0.04	0.107
Gender (female vs. male)	0.10	−0.12–0.32	0.365
Duration of diabetes (years)	0.07	−0.15–0.29	0.522
Number of medications	−0.15	−0.37–0.07	0.178
Number of comorbidities	−0.11	−0.33–0.11	0.314
Baseline medication adherence score	−0.22	−0.44–0.00	0.051

Model R^2=0.48, Adjusted R^2=0.38, P<0.001. HbA1c: Glycated hemoglobin, CI: Confidence interval

Table 16: Multiple linear regression analysis of factors associated with HbA1c reduction in the intervention group

Variable	Standardized β coefficient	95% CI	P-value
Improvement in medication adherence	−0.45	−0.66–−0.24	<0.001
Baseline HbA1c (%)	−0.38	−0.59–−0.17	<0.001
Frequency of app use (times/day)	−0.24	−0.44–−0.04	0.021
Age (years)	0.12	−0.08–0.32	0.241
Gender (female vs. male)	−0.08	−0.28–0.12	0.427
Duration of diabetes (years)	0.05	−0.15–0.25	0.621
Number of medications	0.10	−0.10–0.30	0.318
Education level (per category increase)	−0.15	−0.35–0.05	0.142
Improvement in DSMQ score	−0.22	−0.42–−0.02	0.032

CI: Confidence interval, HbA1c: Glycated hemoglobin A1C, DSMQ: Diabetes self-management questionnaire, Model R^2=0.57, Adjusted R^2=0.49, P<0.001. Negative β coefficient indicates greater HbA1c reduction

CONCLUSION

The implementation of a personalized smartphone application for medication reminders was shown to enhance medication adherence, glycemic control and overall health in older adults with type 2 diabetes. The participants who used the app showed significantly improved medication adherence and experienced significant improvements in glycemic control, BP and lipid levels. Additionally, the app stands out because it helps users manage themselves, increases their quality of life and receives high praise from them for its effectiveness. Having mobile health tools for the elderly may assist in dealing with chronic diseases. It is important for future research to analyse if these technologies can be sustained, improved and added to regular healthcare services.

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