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REVIEW

Pharmacist-Led Digital Health Interventions for Patients with Diabetes: A Systematic Review

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Abstract: Digital health interventions have emerged as a promising approach for patient care. The aim of this study was to conduct a systematic review of pharmacist-led digital health interventions for patients with diabetes. The PubMed database was used to select randomized controlled trials that assess the effectiveness of digital health interventions on clinical outcomes among patients with type 1 and 2 diabetes from January 2005 to May 2024. We included randomized controlled trial (RCT) studies on type 1 and 2 diabetes mellitus, analyzing the effects of all digital health interventions by pharmacists, including telephone-based intervention, web-based intervention, and mobile health application, as compared to usual care. The outcomes were a reduction in HbA1c, changes in medication adherence, and reduction of adverse effects. We used the PRISMA reporting standard to implement and report the results. A total of 19 studies were included. Among these, the included digital health interventions were telephone monitoring (n = 15), web-based intervention (n = 2), mobile health application (n = 1), and text-message reminder (n = 1). The findings showed variability: around half of the studies (n = 10, 52.63%) indicated that patients receiving digital health interventions had reduced HbA1c levels compared to those receiving usual care, while five studies (26.31%) found no difference between the intervention and usual care. Five studies (26.31%) showed that such interventions increased medication adherence, while two studies (10.53%) found no difference when compared to standard care. Effectiveness of the intervention is related to several factors, including practicability and patient engagement, frequency of the intervention, and the provision of personalized communication. Tailoring interventions to individual patient profiles and providing adequate support for enhancing practicability of these tools may improve their effectiveness. Further research assessing the cost-effectiveness of such intervention is necessary to inform healthcare policy.

Keywords: pharmacist, digital health intervention, diabetes, clinical outcomes, pharmaceutical care

Introduction

Diabetes is a progressive and chronic metabolic disease, characterized by elevated blood glucose levels, which over time can result in organ damage and increase the risk of other metabolic conditions such as renal impairment, hypertension, and cardiovascular diseases.[1] Diabetes affects about 422 million people worldwide and is the cause of 1.5 million deaths each year, of which the majority are living in low- and middle-income countries.[2] Pharmacotherapy is the cornerstone of diabetes treatment, involving antidiabetic agents such as insulin, sulfonylureas, and biguanides.[2] Various factors may influence treatment outcomes among patients with diabetes, such as medication adherence, the presence of medication-related problems, and dietary compliance, which underscore the importance of personalized care and monitoring. Previous study conducted regarding medication adherence of diabetic patients showed that about 50% of patients were non-adherent towards their prescribed antidiabetic medication.[3]

Pharmacists play an important role in diabetes management, particularly through direct patient monitoring. Unlike other healthcare professionals, pharmacists have the advantage of more frequent patient interactions, as they do not require prior authorization for consultations.[4] Previous study showed that pharmaceutical care was associated with

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reductions in HbA1c (Hemoglobin A1c) by 1.24% in 2 years compared to the control group, which only reduced by −0.59%.[5] Orabone et al evaluated a pharmacist-managed diabetes program and found that pharmacist interventions in primary care resulted in reduced HbA1c and increased medication adherence.[6]

Digital health interventions (DHI) are defined as the use of digital and information technology to support and enhance health systems, patient care, and health outcomes.[7] The adoption of digital health intervention can further improve diabetes management by providing tools for continuous monitoring and personalized patient engagement. Pharmacist-led digital health intervention has some advantages including cost and resource efficiency. To our knowledge, no study has systematically reviewed the effectiveness of pharmacist-led digital health intervention for patients with diabetes. Therefore, the objective of this review was to summarize the characteristics and effectiveness of pharmacist-led digital health intervention for people with diabetes.

Material and Methods

Search Strategy

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement was used to guide the reporting of the findings. A systematic search was conducted within the PubMed database covering the period from January 2005 to May 2024. The search strategy included terms related to: i) digital health interventions; ii) pharmacist and pharmaceutical care; and iii) diabetes. The following keywords were used: ((Telepharmacy[tiab] OR automated medication system[tiab] OR electronic medication order entry[tiab] OR electronic medication management system[tiab] OR automated dispensing[tiab] OR computerized reminder system[tiab] OR information technology[tiab] OR medication ordering entry-[tiab] OR electronic medication ordering and administration system[tiab] OR remote consultation[tiab] OR electronic consult*[tiab] OR digital technology*[tiab] OR teleconsult*[tiab] OR mhealth[tiab] OR m-health[tiab] OR multimedia[tiab] OR virtual[tiab] OR mobile health[tiab] OR telemedicine[tiab] OR electronic health record[tiab] OR telehealth[tiab] OR telecare[tiab] OR telehealth care[tiab] OR mobile health intervention*[tiab] OR mobile applications[tiab] OR mobile telemedicine[tiab] OR mcare[tiab] OR m-care[tiab] OR mobile communication[tiab] OR mobile technology*[tiab] OR multimedia technology*[tiab] OR mobile device*[tiab] OR app[tiab] OR apps[tiab] OR mobile app*[tiab] OR website*[tiab] OR internet consultation*[tiab] OR internet monitoring[tiab] OR video consultation*[tiab] OR video monitoring[tiab] OR telephone*[tiab] OR mobile phone*[tiab] OR smartphone*[tiab] OR smart-phone*[tiab] OR text message*[tiab] OR text messaging[tiab] OR SMS[tiab] OR short message*[tiab] OR multimedia message*[tiab] OR multi-media message*[tiab] OR website platform[tiab] OR web-based medication platform[tiab] OR web-based application[tiab] OR web-based tool[tiab] OR electronic health[tiab] OR ehealth[tiab] OR e-health[tiab])) AND (Pharmacist*[tiab] OR pharmaceutical care[tiab]) AND (diabetes[tiab]).

Inclusion and Exclusion Criteria

We included randomized controlled trial (RCT) studies performed on adults with type 1 and 2 diabetes mellitus, assessing the impact of digital health interventions led by pharmacists. The outcomes were the reduction in HbA1c or fasting blood glucose (FBG), changes in medication adherence, fasting plasma glucose (FPG), two-hour postprandial glucose (2hPG) and reduction of adverse events, such as hypoglycemia. Studies were excluded if they: (a) were not related to digital health interventions, (b) were not an RCT, (c) did not focus on diabetes mellitus, (d) were literature reviews/systematic reviews, RCT protocols, or conference abstracts, or (e) did not include a pharmacist in the intervention.

Screening and Data Extraction

Two investigators (AC and FF) screened the titles and abstracts generated from the databases using the predetermined criteria. Any discrepancies between the two reviewers were then resolved through discussion with a third reviewer (WNI). Following initial screening, the full text of potentially relevant papers were further assessed to identify eligible studies. The process of study selection was presented using an adapted PRISMA diagram. The process of data extraction was conducted using a standardized data collection form for all included studies. Data extracted included general characteristics of the studies, study design, and main findings.

Results

Literature Search and Selection Process

Figure 1 presents a flowchart outlining the article selection process. An initial database search yielded 49 articles from PubMed, from which titles and abstracts were screened. This initial screening led to the exclusion of 12 studies, resulting in 37 studies eligible for full-text review. Following this second-level screening, 19 articles met the inclusion criteria and were incorporated into the final analysis.

Characteristics of the Studies

Table 1 shows a summary of all the results taken from 19 included studies. Half of the included studies were conducted in the United States of America (n = 10),[8,10,13,16,18–20,24–26] and the rest were conducted in France (n = 2),[9,14] China (n = 1),[11] Thailand (n = 1),[12] Iran (n = 1),[15] Brazil (n = 1),[17] England (n = 1),[21] Malaysia (n = 1),[22] and Jordan (n = 1).[23] Sample size of the studies ranged from 27 to 3734 patients. The types of digital interventions were telephone-based (n = 15), web-based (n = 2), mobile-based (n = 1), and text-message reminder (n = 1). More than half of the studies assessed HbA1C (n =15)[9–13,15,17–24,26] The remaining evaluated changes in medication adherence (n = 7).[8,11,12,14,15,18,25] Another study investigated the changes in FPG, 2hPG, and adverse event.[11]

Telephone-Based Intervention

We found that fifteen studies used telephone-based monitoring.[8–11,13,15–17,19–21,23–26] Eight studies revealed the digital health interventions improved HbA1c level as compared to usual care[10,11,13,17,21,23,24,26] and a total of five studies found no difference compared to the control group.[9,15,18–20] Other than HbA1c, a total of five studies use telephone-based intervention to assess medication adherence. Three studies showed an increase in medication adherence, while two studies revealed no significant impact of digital health intervention on medication adherence (Table 2). One study showed that with the help of DHIs, pharmacists could document more adverse events compared to usual care, showing that DHIs could as well help in the process of early detection of adverse events.[16] Pharmacists prefer telephone interventions because they are convenient and provide

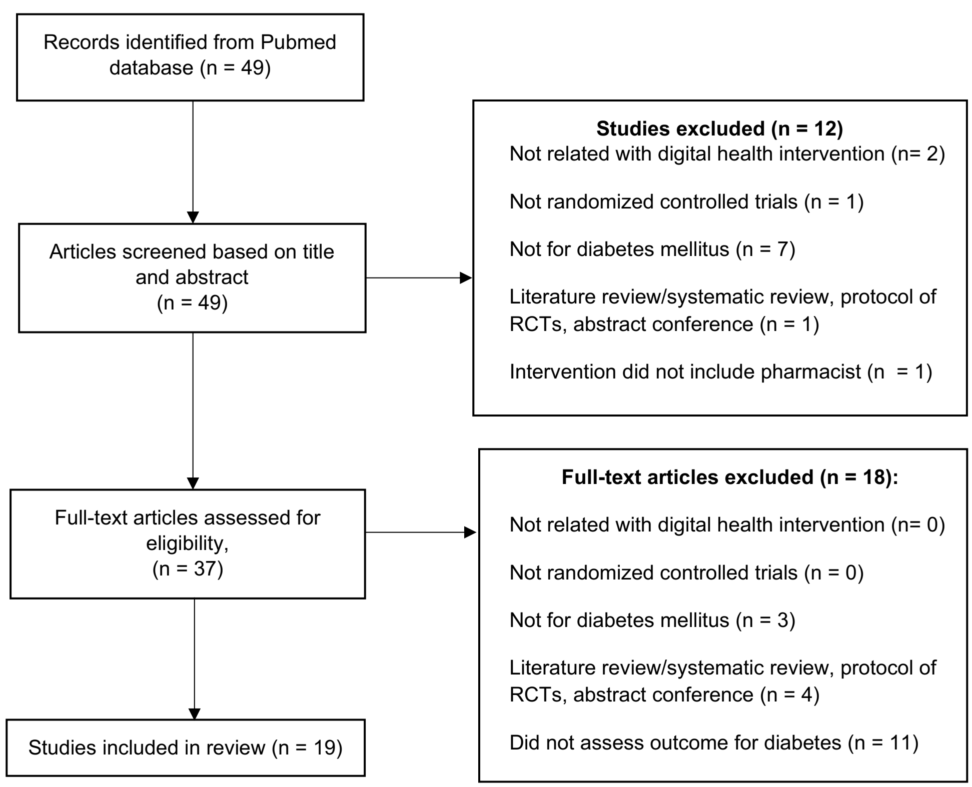

Figure 1 Flow Diagram of Systematic Review.

Table 1 General Characteristics of Studies

No	Author, Publication Year	Setting	Country	Subject	Design	Outcome
Type 1 Diabetes Mellitus						
1.	Cohen et al, 2019[8]	1 medical center	United States of America	Veterans with type 1 or type 2 diabetes with an A1C 7.5% within the last six months, concomitant depression as defined by International Classification of Diseases (ICD)-9 codes 311 or 296.2 to 296.3	Open label-RCT	Adherence
2.	Gay et al, 2006[9]	1 clinic and 44 pharmacies	France	Type 1 diabetes patients for more than one year, aging 8–17 years old with HbA1c levels ≥8%	RCT	HbA1c
Type 2 Diabetes Mellitus						
1.	Gerber et al, 2023[10]	1 academic medical center	United States of America	Adult African American or Latinx patients (age 21–75) with type 2 diabetes and elevated HbA1c (≥8%)	RCT	HbA1c
2.	Wang et al, 2022[11]	1 hospital	China	18–65 years of age, diagnosis of Type 2 Diabetes Mellitus (T2DM) and hypertension based on the Chinese guidelines for the prevention and treatment of type 2 diabetes mellitus (2017 edition) and the Chinese guidelines for the management of hypertension	RCT	Adherence, adverse event, FPG, 2hPG and HbA1c
3.	Poonprapai et al, 2022[12]	1 hospital	Thailand	≥ 65 years of age, a diagnosis of type 2 diabetes, inadequate glycaemic control (glycosylated hemoglobin (HbA1c) level > 7% or 53 mmol/mol	RCT	Adherence and HbA1c
4.	Peasah et al, 2019[13]	2 medical clinic	United States of America	Patient aged 18 to 65 years old, taking at least 1 oral antidiabetic medication, and had an HbA1c of 7% within the last 12 months	RCT	HbA1c
5.	Gautier et al, 2021[14]	114 pharmacies	France	Patients were 18 years old with T2DM being treated with at least one oral antidiabetic drug that was delivered monthly	RCT	Adherence
6.	Sarayani et al, 2018[15]	1 pharmacy	Iran	Patients over age 18 with type-2 diabetes	RCT	Adherence and HbA1c
7.	Schiff et al, 2019[16]	26 clinic	United States of America	Patients over age 18 who received newly prescribed medication for diabetes	Cluster RCT	Adverse effects
8.	Aguiar et al, 2018[17]	1 care clinic	Brazil	Patients with type 2 diabetes, aged 40–79 years and glycosylated haemoglobin (A1C) level ≥ 7.0%.	RCT	HbA1c
9.	Lauffenburger et al, 2019[18]	1 health insurer	United States of America	Patients ≥18 years of age who filled 1 or more oral hypoglycemic agents within the 12 months prior to randomization and who had evidence of poor diabetic control (HbA1c ≥8%)	Pragmatic RCT	Adherence and HbA1c

(*Continued*)

Table 1 (Continued).

No	Author, Publication Year	Setting	Country	Subject	Design	Outcome
10.	O'Connor et al, 2014[19]	1 integrated care consortium, 1 insurance agency, and 2 clinics	United States of America	Diabetes patients aged 18–75 who received clinical care at designated clinic or medical center involved in this study for at least 15 months before study enrollment, and were prescribed a new class of medication for A1C, blood pressure (BP), or low density lipoprotein (LDL) cholesterol uncontrolled at the time of medication prescription (A1C ≥8%, systolic BP [SBP] ≥140 mmHg, or LDL cholesterol ≥100 mg/dL).	Cluster RCT	HbA1c
11.	Odegard et al, 2005[20]	1 clinic	United States of America	All adult patients with type 2 diabetes, taking at least one oral diabetes medication, with HbA1c ≥9%	RCT	HbA1c
12.	Lyons et al, 2015[21]	Patients recruited through an internet and mail-order pharmacy	England	Patients aged > 18 prescribed at least one oral medication for type 2 diabetes and/or lipid regulation were recruited through 'Pharmacy2U', a UK National Health Service (NHS)-contracted internet and mail-order pharmacy	RCT	HbA1c
13.	Wasif Gillani, 2016[22]	Diabetic clinics and hospital	Malaysia	Patients with type 2 diabetes diagnosed by a physician at least six months before the study, aging 18–75 years old, with HbA1c ≥7.5% but less than 11%	RCT	HbA1c
14.	Jarab et al, 2012[23]	1 hospital	Jordan	Type 2 diabetes patients diagnosed at least 1 year prior to the study aged ≥ 18 years old, who took at least 1 prescribed medication for diabetes, and HbA1c levels ≥7.5%	RCT	HbA1c
15.	Choe et al, 2005[24]	1 university-affiliated primary care	United States of America	Type 2 adult diabetes patients not older than 70 years old with recent HbA1c levels ≥8%	RCT	HbA1c
16.	Odegard and Christensen, 2012[25]	4 Pharmacies	United States of America	Patients with type 2 diabetes aging >18 years old and are using at least one oral prescription diabetes medication, which are overdue for prescription refills by 6 days or more	RCT	Adherence
17.	Lauffenburger et al, 2019[26]	1 health insurer	United States of America	Patients 18 years or older with type 2 diabetes, in claims or previous fills of an oral hypoglycemic medication, who filled 1 or more basal (long-acting) insulin prescriptions in the 6 months before random- ization	3 armed pragmatic RCT	HbA1c

privacy for patients. However, a drawback is the potential language barrier, as some studies only include one language, excluding patients who do not speak it.

Web-Based Intervention

Among the articles we studied, two studies used web-based interventions.[9,22] Web-based interventions can be described as a mostly self-guided program, executed by an online program operated through a website and used by consumers seeking health-related assistance.[27] Usually, the intervention program itself attempts to create positive change and/or

Table 2 Main Findings of the Studies

No	Author, Publication Year	Intervention (n, Mean Age, % Female, Frequencies)	Control (n, Mean Age, % Female)	Follow-Up Period	Main Findings
Type 1 Diabetes Mellitus					
1.	Cohen et al, 2019[8]	Telepharmacy (phone calls, medication review) for counseling (n = 13, 63.1 ± 12.2, 0%, twice in 6 months for phone calls, everyday for medication reminder)	Usual care/ nurse-led telehealth (n = 14, 60.5 ± 9.4, 86.7%)	6 months	No significant raise in diabetes medication adherence (mean of 3.9%) compared to control patients (mean of 2.6%)
2.	Gay et al, 2006[9]	Telemonitoring through a software capable to download, analyze, and print blood glucose monitoring data (n = 50, 13.2 ± 2.7, 42%, every 2 weeks)	Usual care (n = 50, 13.5 ± 2.5, 36%)	6 months	No significant difference in HbA1c decrease found between children in the intervention (−0,10 ± 1.10) and control group (0.10 ± 1.05)
Type 2 Diabetes Mellitus					
1.	Gerber et al, 2023[10]	Telepharmacy (phone calls, remote support) for counseling (n = 109, 56.0 ± 9.3, 70.6%, every 2–3 months)	Usual care (n = 112, 54.5 ± 9.6, 68.8%)	24 months	Lower mean HbA1c −0.79% in interventions patients compared to −0.24% in control patients (P < 0.005)
2.	Wang et al, 2022[11]	Telepharmacy (phone calls) for medication education, medication taking reminder and counseling (n = 40, 42, 42.5%, every 2 weeks)	Usual care (n = 40, 43, 40%)	3 months	Increased in medication adherence 90% in interventions patients and 52.5% in control patients (P < 0.001) Significant differences in HbA1c 6.5% in interventions patients and 7.0% in control patients (P = 0.007) Differences in FPG 6.50 in interventions patients and 7.00 in control patients (P = 0.004) Differences in 2hPG 8.45 in interventions patients and 9.35 in control patients (P = 0.007) Five recorded adverse event in control patients (hypoglycemic [n = 2], rash [n = 2], and nausea [n = 1]) and zero in interventions patients
3.	Poonprapai et al, 2022[12]	Mobile-based intervention (provided information, medication reminder, and counseling using mobile apps) (n = 78, 67.36 ± 5.72, 60.3%, daily for 3 months for diabetes education, 4 times/day for medication reminder)	Usual care (n = 79, 67.80 ± 6.18, 59.5%)	9 months	Lower mean HbA1c −0.97% in interventions patients compared to −0.12% in control patients (P = 0.001) Increased medication adherence 1.61 ± 3.4 in intervention group compared to 0.94 ± 1.71 in control group
4.	Peasah et al, 2019[13]	Telepharmacy (phone calls) for medication refill reminder, medication reminder, and counseling (n = 39, 64.3 ± 10.7, 54%, weekly)	Usual care (n = 39, 59.0 ± 10.0, 41%)	3 months	Lower mean HbA1c −0.35% in interventions patients and increased mean HbA1c 0.338% in control patients

(*Continued*)

Table 2 (Continued).

No	Author, Publication Year	Intervention (n, Mean Age, % Female, Frequencies)	Control (n, Mean Age, % Female)	Follow-Up Period	Main Findings
5.	Gautier et al, 2021[14]	Telepharmacy (text message) for medication taking reminder, lifestyle advices, and follow-up medical appointments (n = 156, 60.2 ± 10.6, 47.1%, daily)	Usual care (n = 140, 64.8 ± 9.9, 36.5%)	3 months	Increased medication adherence 0.58 ±1.29 in interventions patients and 0.12±1.27 in control patients (P = 0.004)
6.	Sarayani et al, 2018[15]	Telepharmacy (phone calls) for counseling drug therapy problem and blood glucose level (n = 40, 53.4 ± 10.3, 45.1%, 16 calls in 3 months)	Usual care (n = 44, 56.7 ± 11.5, 38%)	9 months	Decreased mean HbA1c 0.81±1.12 in interventions patients and 1.03±1.41 in control patients. Increased medication adherence with high level of adherence patients 63% in interventions patients and 22.9% in control patients
7.	Schiff et al, 2019[16]	Telepharmacy (phone calls) for counseling of new symptom including the severity level (n = 776, 57.2, 66.6%, 10 calls in two weeks)	Usual care (n = 776, 59.7, 74.9%)	4 months	Intervention patients were significantly more likely to have adverse effects (277 vs 164 adverse effects, p < 0.0001, and 177 vs 122 patients discontinued with documented adverse effects, p < 0.0001)
8.	Aguiar et al, 2018[17]	Telepharmacy (phone calls) and medication chart (n = 36, 61.1 ± 7.9, 69.4%, 1–2 calls between 2–6 months)	Usual care (n = 37, 62.4 ± 8.2, 64.9%)	12 months	Lower mean HbA1c −0.79% in interventions patients compared to −0.16% in control patients (P = 0.010)
9.	Lauffenburger et al, 2019[18]	Telepharmacy (phone calls) for medication reviewing and giving suggestion to improve the patients diabetes control (n = 684, 54.6 ± 8.4, 39.8%, 1–6 calls)	Usual care (n = 678, 54.9 ± 8.1, 34.6%)	12 months	No improvement in HbA1c in patients subjected to intervention (mean change = −0.75±1.96) with usual care (mean change = −0.79 ±2.01) and no improvement in adherence either.
10.	O'Connor et al, 2014[19]	Electronic medical records (EMRs), Telepharmacy (phone calls) for counseling (n = 1220, 61.67 ± 13.03, 51.1%, 1 call)	Usual care (n = 1158, 62.04 ± 13.37, 53.1%)	2 months and 6 months	No significant decrease of HbA1c in patients in the intervention arm (change from baseline −1,08%) compared to patients in control arm (change from baseline −0,90%)
11.	Odegard et al, 2005[20]	Electronic notation in medical records and weekly telephone meetings (n = 43, 51.6 ±11.6, 48%, weekly)	Usual care (n = 34, 51.9 ± 10.4, 38%)	6 months	No significant reduction in HbA1c levels in intervention arm compared to control arm
12.	Lyons et al, 2015[21]	Telephone consultations and a medicine reminder chart (n = 340, 69.9 ± 9.2, 39.1%, 2 calls 4–6 weeks apart)	Usual care (n = 337, 69.9 ± 10.1, 43.9%)	6 months	Intervention group has twice the proportion of participants achieving HbA1c level of 7% (66.7%, n=16) compared with the control group (31.3%, n=5)

(*Continued*)

Table 2 (Continued).

No	Author, Publication Year	Intervention (n, Mean Age, % Female, Frequencies)	Control (n, Mean Age, % Female)	Follow-Up Period	Main Findings
13.	Wasif Gillani, 2016[22]	Telemonitoring through a web-enabled glucometer connected to an online portal (n = 50, 53 ± 10.19, 46%, daily)	Usual care (n = 50, 54 ± 10.29, 42%), and Pharmacist Intervention (n = 50, 52 ± 9.81, 42%)	6 months	Direct pharmacist intervention is better than the telemonitoring and control arm in improving patient's clinical outcomes
14.	Jarab et al, 2012[23]	Telepharmacy (phone calls) to review the prescribed medication and answering patient questions (n = 77, 63.4 ± 10.1, 42.4%, weekly for 8 weeks)	Usual care (n = 79, 65.3 ± 9.2, 44.2%)	6 months	A significant mean decrease in HbA1c was noticed in the intervention arm (0,8%) compared to the control arm (0,1%)
15.	Choe et al, 2005[24]	Telepharmacy (phone calls) for counseling (n = 36, 52.2 ± 11.2, 51.2%, 1 per month)	Usual care (n = 29, 51 ± 9.0, 53.9%)	12 months	Intervention group has more of a significant decrease in HbA1c levels (mean decrease = 2.1 ± 2.5) compared to the control group (mean decrease = 0.9 ± 2.0)
16.	Odegard and Christensen, 2012[25]	Telepharmacy (phone calls) for counseling (n = 120, 65 ± 13, 53.8%, calls initiated for missed refills)	Usual care (n = 145, 61 ± 13, 50.3%)	12 months	At 12 months, MPR (Medication possession ratio) was significantly improved for the study group compared with the control group (difference between groups, P = 0.01). Intervention showed greater effect for patients with baseline MPR less than 80%. Likelihood of MPR above 80% at the 12 month follow-up for any patient significantly favored the intervention group
17.	Lauffenburger et al, 2019[26]	Telepharmacy (phone calls) for counseling with different intervention intensity between the three arms. (1st arm = untargeted low intensity, 2nd arm = partially targeted moderate intensity, 3rd arm = highly targeted high intensity) (n 2nd arm = 1873, 55.4 ± 11.3, 39.3%; n 3rd arm = 1862, 55.9 ± 1.7, 40.7%,1st arm = 2 follow-up calls, 2nd arm = 6 follow-up calls, 3rd arm = 12 follow-up calls)	Untargeted low intensity care (n = 1861, 55.9 ± 11.0, 39.7%)	12 months	Glycemic control was similar in arm 2 and arm 1 (absolute HbA1c level difference, –0.15%; 95% Confidence Interval (CI), –0.34% to 0.05%) but was better in arm 3 (absolute HbA1c level difference, –0.25%; 95% CI, –0.43% to –0.06%)

improve patient's knowledge, awareness, and understanding by providing good health-related material and use of interactive Web-based components.[27]

This intervention enabled pharmacists to upload patient data, including blood glucose levels, which facilitated monitoring of disease progression and informed the selection of more effective treatment options.[9,22] Unfortunately, these two studies show that web-based interventions did not significantly lower the level of HbA1c compared to the control group. The disadvantage of both studies is that patients did not directly use the web or software; instead, it was primarily operated by the pharmacist.

Mobile Health Application

One study used a mobile health application and another one used text message reminders.[12,14] Patients used the mobile application to consult directly with the pharmacist, receive medication reminders, and access information about diabetes. The result was positive with a lower mean of HbA1c in the intervention group compared to the control group and higher medication adherence compared to the control group from baseline. Mobile-based interventions have the advantage of supporting multiple languages, with the application translating according to the pharmacist's native language. However, the disadvantage is that patients need to know how to operate the application.

Text-Message Reminder

Text messages were used in one study.[14] In the article we reviewed, the text messages were sent automatically daily for three months in an SMS group and contained medication reminders sent every day and educational narrative content sent during the first 5 days of a week. The narrative contents were divided into chapters, containing advice and important information relevant to type 2 diabetes, such as giving advice to increase physical activities, about food, lifestyle choices, etc.

For the first day of the week, patients were sent a general fact, the next day they were sent a relevant information. The third day, patients were sent an open question, the fourth a tip, and the fifth a message designed to encourage them. Patients were then subjected to follow ups through assessment after the first, second, and third months. During the third month's follow up, patient's satisfaction of the SMS service was evaluated. For next three months, no text messages were sent, and assessments were then conducted again at the end of that point (6th month follow-up). Using daily reminder text messages also showed an improvement in patient medication adherence compared to usual care.

Discussion

To our knowledge, this is the first systematic review to assess the effectiveness of pharmacist-led digital interventions for patients with type 1 and type 2 diabetes, assessing outcomes related to diabetes treatment, such as HbA1c and FBG, medication adherence, and reduction of adverse effects. Overall, the results were inconsistent. Around half of the studies (n = 9, 47.37%) showed that these interventions reduced HbA1c compared to usual care, while five studies (26.31%) showed there was no difference between the intervention and the control group.[9,15,18–20] Four studies (21.05%) showed an increase in medication adherence compared to the control group,[11,14,15,25] while two studies (10.53%) showed no difference compared to the control group.[8,18]

The effectiveness of the intervention is influenced by several factors, including its practicability and patient engagement, the frequency of intervention, the provision of personalized communication, and the integration with clinical care through automation.

We found that telephone-based monitoring was the most frequently used (n = 15, 78.95%) digital health intervention. Similarly, a previous systematic review evaluating the use of digital technology by community pharmacists to improve public health also found that telephone-based interventions were the most commonly used digital health intervention method compared to other strategies such as mobile application and web-based intervention.[28] We observed that telephone-based interventions showed superior efficacy in reducing HbA1c levels and increasing medication adherence compared to other forms of digital health interventions. Telephone-based interventions are relatively more straightforward, which might explain their effectiveness in this demographic. For instance, a study focusing on digital health interventions for younger individuals (aged 16–35 years) found that web-based interventions, such as mental wellness websites, were more commonly utilized.[29] This suggests that the simplicity of the intervention's approach may play a crucial role in its adoption and effectiveness, particularly among older patients with chronic diseases such as diabetes.

In our review, several studies (n = 7, 36.84%) found no significant difference in diabetes outcomes between the digital health intervention and usual care. The impersonal nature of these tools, ie, the lack of direct human interaction and personalized communication, which can add additional burden of care to both providers and patients, was cited as a barrier to the implementation of this intervention.[30] In addition, access to digital technology, behavioral factors, and issues related with practicability of the intervention may also hinder the effectiveness.[21,22] Future studies should consider these factors when designing interventions for patients with diabetes.

Another reason would be the frequencies of interventions. Three out of five studies utilizing telephone-based interventions that showed no significant difference had a frequency of phone calls ranging only from one to six. This suggests that a limited number of calls were insufficient to produce a meaningful impact on patient outcomes. In a study by Lauffenburger et al, patients did not receive the necessary frequency of interventions. Of the 700 patients, only 202 responded to the first call, 106 (52.5%) continued to the second call, and only 52 (25.7%) received three or more calls. This low frequency of interventions was likely insufficient, especially given the extended 12-month follow-up period.[18] A similar outcome was observed in one study, where no significant improvement in HbA1c levels was found.[19] Although the study used a phone call system, the calls had a median duration of less than 5 minutes, which appeared insufficient to yield significant results.

The follow-up period in the studies included in our review ranged from 3 to 24 months. Although 3 months is relatively short, this period was considered sufficient for evaluating HbA1c levels, as demonstrated in two studies.[11,13] This assessment is based on the average 3-month lifespan of red blood cells, allowing HbA1c levels to reflect any changes in lifestyle or medication adherence resulting from the intervention.[31] However, extended follow-up periods would offer a more comprehensive view of the long-term impact of digital interventions on medication adherence and disease management. Prolonged intervention duration may also gradually influence patients' medication-taking behaviors.[32]

A study done by Schiff et al showed that patients in the intervention arm is more likely to have adverse effects. This could be caused by the fact that the DHI used in this study works as a media for patients to report adverse drug reactions and its severity. Therefore, the fact that patients in the intervention arm is found more likely to have adverse effects is favorable in terms of early detection of adverse events, and early detection leads to early management of adverse reactions. This makes it easier for medical practitioners including pharmacists to plan change of therapy regimen and education regarding hypoglycemia for diabetic patients, as awareness on symptoms of hypoglycemia is really important.[33]

In a study utilizing automated text-message reminders, the messages remained personalized by the pharmacist, tailored to each patient's profile with specific information on physical activity, diet, and daily lifestyle choices.[14] The automated text messaging yielded positive results, including a reduction in BMI and improved medication adherence; however, it did not lead to significant changes in HbA1c levels. A limitation of automated messaging is the absence of direct pharmacist interaction, which restricts opportunities for patient feedback and questions, thereby diminishing the pharmacist's supportive role. Additionally, studies should explore integrating automated and semi-automated interventions to balance the time efficiency and personalized care provided by pharmacists. Although automated interventions like personalized text messaging showed promising results in improving medication adherence, the absence of direct pharmacist interaction may limit their overall impact. Hence, future studies should investigate hybrid approaches combining automated systems with opportunities for pharmacist feedback. For example, in the study done by Gillani et al, direct pharmacist intervention is still better than telemonitoring and usual care, proving the importance of direct pharmacist involvement.[22]

Digital health intervention could be used not only for disease monitoring but also to assist in the drug management process, eg, the clinical decision support system (CDSS) that provides medication safety alerts to reduce medication errors, such as dosing errors, contraindications, and drug–drug interactions in diabetes treatment.[34] As shown by the study done by Schiff et al, with the help of DHIs, pharmacists could document more adverse events compared to usual care, showing that DHIs could as well help in the process of early detection of adverse events.[16] Nevertheless, this review indicates that there are still few studies addressing digital intervention for medication safety in diabetes. This review could serve as a foundation for further improving existing digital health interventions to enhance their effectiveness.

Pharmacist-led digital interventions for other chronic diseases, such as hypertension, have shown that medication management through digital interventions improved blood pressure control.[33] Similar research conducted for patients with dyslipidemia demonstrated that a basic internet-based health management platform is moderately effective in controlling the patient's diet, physical activity, and tobacco use, thereby providing adequate protection against dyslipidemia.[35] These studies demonstrated that digital health interventions have the potential to improve disease control for chronic diseases.

This study has several potential limitations. First, only the PubMed database was used as a source for articles. However, the decision to limit the search to PubMed was guided by the scope of our research. Our systematic review primarily focused on biomedical and clinical studies, for which PubMed serves as a highly comprehensive and widely recognized source. Second, although all the included studies employed RCTs, there remains a potential risk of selection bias, particularly in unblinded trials where restricted randomization is utilized to maintain equal group sizes.[36] Heterogeneity in the types of interventions included in this review may limit the generalizability of the findings.[37] The strengths of this review include its unique focus on pharmacist-led digital health interventions and its broad inclusion of various clinical outcomes, including HbA1c levels, medication adherence, and adverse effects. This approach provides a comprehensive understanding of the multifaceted impact of these interventions on patient health and supports evidence-based decision-making in digital health care.

Conclusion

This review found that pharmacist-led digital health interventions for patients with diabetes included telephone-based monitoring, web-based intervention, mobile health application, and text-message reminder. The outcomes were inconclusive. While several studies demonstrated positive outcomes, such as reduced HbA1C levels and increased medication adherence, some research did not yield the anticipated results. The effectiveness of the intervention is influenced by several factors, including its practicability and patient engagement, the frequency of intervention, the provision of personalized communication. Further research assessing the cost-effectiveness of such intervention is necessary to inform healthcare policy.

Abbreviations

DHI, Digital Health Intervention; HbA1c, Hemoglobin A1c/glycohemoglobin/glycated hemoglobin; RCT, Random Controlled Trial; FBG, Fasting Blood Glucose; FPG, Fasting Plasma Glucose; 2hPG, Two-hour Postprandial Glucose; CDSS, Clinical Decision Support System; ICD, International Classification of Disease; T1DM, Type 1 Diabetes Mellitus; T2DM, Type 2 Diabetes Mellitus; BP, Blood Pressure; SBP, Systolic Blood Pressure; LDL, Low Density Lipoprotein; EMR, Electronic Medical Record; CI, Confidence Interval.

Disclosure

The authors report no conflicts of interest in this work.

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