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Usability of mHealth in Patient with Type 1 and Type 2 Diabetes Mellitus: A Review

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Abstract

Diabetes mellitus (DM) is a group of metabolic illnesses identified by elevated blood glucose levels. The glycated hemoglobin (HbA1C) test is used to evaluate a person's control of their blood glucose levels. According to a recent study, mHealth interventions may be particularly helpful for assisting patients with diabetes mellitus to self-monitor their status on their HbA1c level. Therefore, this systematic review aims to provide an overview of how mHealth affects individuals with diabetes mellitus, concentrating on HbA1c evaluation. A systematic review was conducted by reviewing the PubMed, Google Scholar, and Mendeley databases for randomized control trials published between February 2017 and September 2023. The studies of mHealth on the result of HbA1c were then examined. A drop in HbA1c was seen in all intervention groups. The overall average reduction in HbA1c across all intervention groups was - 0.79%, while the reduction in control groups was - 0.42%. The influence of mHealth could significantly reduce HbA1c levels. Studies show that HbA1c decreased more in patients who underwent a 3 to 6-month intervention. This study discovered 12 papers that discuss health for people with diabetes mellitus type 1 and 2. This study found that mHealth interventions significantly lower HbA1c in DM patients. For further research, bigger sample sizes and data on self-care results are needed. The views and perspectives of patients regarding the physical characteristics and design aspects of different interventions—mobile applications, texts, and phone calls—need to be further investigated.

Keywords: Diabetes mellitus, HbA1c, mHealth

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Introduction

DM is a group of metabolic illnesses defined by increased blood glucose levels, which leads to major consequences and major mortality and morbidity worldwide over time.[1] Increasing levels of obesity and body mass index, unhealthy eating habits, inactivity and lack of physical activity, increasing smoking, and other factors are the main contributors to DM. The term "mHealth" was first defined and introduced as "mobile computing, medical sensors, and communications technologies for health care". Since 2003, mHealth has become one of the most critical fields of technology that reflects the significant advancements in computing, sensors, mobile communications, and the internet to enhance the execution of healthcare.[2]

From a clinical perspective, all diabetes mellitus treatment recommendations suggest self-care of blood glucose levels as an important extra strategy for improving diabetes mellitus treatment and quality of life as well as reducing long-term effects and HbA1C levels.[2] One way to evaluate someone's glucose management is with the HbA1C test. The test provides a percentage of the mean blood sugar level for the previous ninety days.[3] Hemoglobin gets coated with glucose from the bloodstream and becomes glycated. Higher blood glucose levels reflect on the hemoglobin protein's surface, where they bond to the hemoglobin protein and cause an increase in the A1c score.[4]

Good self-management can prevent diabetic complications.[5] Strategies for self-management include keeping an eye on blood sugar levels, taking prescription drugs as directed, starting and maintaining lifestyle changes, and adjusting to the psychological and physical effects of the condition.[6–8] This element of DM treatment is still underdeveloped globally. Improving mechanisms for and actively supporting patient self-management can encourage long-term behavior change, reduce health consequences, and lower associated costs.[9]

DM currently affects 573 million adults globally, with that figure estimated to increase to 643 million by 2030 and 783 million by 2045.[10,11] Throughout the next 30 years, there is expected to be a sharp increase in the number of diabetes mellitus diagnoses. As a result, it puts increasing strain on care delivery systems and necessitates the development of low-cost solutions to assist DM patient self-management.[12] People with DM may enhance their ability to take care of themselves and control their blood sugar levels by participating in traditional DM education programs, such as doctor visits. Conversely, people may not interact with medical professionals very often because of scheduling limitations, transportation issues, expensive office visits, or longer intervals between appointments. Additionally, data indicates that web-based or mobile solutions are particularly helpful for patients living in remote places with limited access to clinics and hospitals.[13]

According to recent study, mHealth interventions may be especially beneficial for promoting diabetic self-management practices.[1,2,5,14] Mobile technology (for example, cell phones) enables highly adaptable new approaches to diabetes mellitus management.[15] A number of mHealth have been developed to assist patients with diabetes mellitus in self-monitoring their condition and providing DM knowledge and guidance.[9] The potential for mHealth to promote self-management has expanded due to its convenience, low cost, and accessibility.[7,11]

Over 6.5 billion individuals globally currently own smartphones. About five hundred million of them use smartphone apps to manage

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chronic health conditions, diets, and exercise.[16] In both developed and developing countries, smartphones are widely used. They've shown a lot of potential in offering individualized medical guidance.[17]

Approximately 1800 of more than 50,000 healthcare apps were created specifically for DM management.[1,14] Publishers and developers of mobile apps believe that DM treatment has the largest prospective market of any health field in digital health.[7] Features involving blood glucose meter connectivity, real-time feedback, medicine, fitness tracking, DM education, emotional support, tracking of sugar and glucose levels, food composition and menu change recommendations are currently included in DM management applications.[1,7,9,14]
Therefore, the purpose of this systematic review is to summarize the available literature on the effects of applying mHealth on laboratory-examined HbA1c in persons with DM. Focusing on HbA1c because it is a reliable measure of the result of all treatments.

Methods

The inclusion criteria for articles were as follows: (1) articles written in English; (2) original research; (2) full accessed articles; (3) issued between February 2017 and September 2023; (4) published in PubMed, Google Scholar, and Mendeley databases; (5) keywords developed around "mHealth", "diabetes mellitus", iii) "HbA1c", and other common diabetes mellitus terms. The exclusion criteria were: (1) non-English articles; (2) duplicate publications; (3) inability to access full text or extracted data; (4) review articles.

A two-step process was used for study selection. Reviewers independently assessed all identified titles and abstracts using the specified inclusion and exclusion criteria. After initial abstract screening, reviewers independently screened the full text of potentially relevant articles.

Articles discussing randomized control trials showing that diabetes mellitus-specific mHealth can be therapeutically beneficial for individuals with the disease. Given the rapid improvements in the mHealth field, included studies were published between 2017 and 2023 to ensure the most up-to-date material was included. Since HbA1c is the most often examined and evaluated clinical outcome related to DM technology therapy, studies reporting HbA1c as one of the key outcomes were included in this comprehensive review.

Supporting data, such as author, year, study design, intervention and control groups, baseline and follow-up HbA1c values, type of DM, sample size, and main findings are included in the Table 1.

Results and Discussion

The primary study features of the 12 included trials are summarized in Table 1. All studies used HbA1c levels as either the primary or secondary outcome of the experiment. The difference in mean average HbA1c was determined by compiling relevant research containing intervention groups (by applying mHealth interventions) and control groups (usual care). The changes in HbA1c for both the intervention and control groups as a percentage from the beginning to the end of the experiment.

All studies were randomized control trials, as required by the review inclusion criteria, with distinct digital mHealth treatments investigated in each clinical investigation. Additional patient outcomes included in the trials were glucose, Postprandial Blood Glucose (PBG) level, body mass index or body weight, Fasting Blood Glucose (FBG) concentrations, and hypoglycemic events,

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vital signs, anthropometry, fructosamine level, and fasting lipids level, user satisfaction to the app, Diabetes Knowledge Test (DBK), Self-Efficacy Scale (SES), self-management, psychosocial monitoring.

A total of 1650 people were involved in the 12 included trials; 1352 of them received a mHealth intervention, whereas 298 were part of the control group. There were between 10 and 693 participants in the experiment. The mean age of the intervention group was 48.29 years, while that of the control group was 50.84 years.

In the intervention group, there were 52.11% male participants, while in the control group, there were 548.52% male participants. Based on the statistics, the intervention group's average length of diabetes mellitus was 14.78 years, while the control group's average duration was 14.67 years.

Table 2 compares HbA1c levels between intervention and control groups in the 12 trials included in this review. Across the 12 included studies, a drop in HbA1c was seen in all intervention groups. 5 out of 6 studies found an increase in HbA1c in the control group. In all 12 trials, the intervention favored the control group. The overall average reduction in HbA1c across all intervention groups was - 0.79%, while the reduction in control groups was - 0.42%.

To improve HbA1c, good eating habits, physical activity, and medication adherence are all critical in diabetes mellitus, but self-management apps might help and effectively motivate the patients.[18] The findings of this study have found that mHealth can help diabetes mellitus patients to improve their self-management and HbA1c levels from a total of 1650 participants across 12 RCTs. The various interventions, such as text messages, mobile apps, interactive telephone, websites, video conferences, and devices, may also explain the impact of mHealth on HbA1c.[9,12,19] A previous study found similar results, hypothesizing that interactive treatment could help remote management of diabetes mellitus healthcare better. Research revealed that receiving text messages (whether motivational or instructive) or being interactive with the physicians resulted in a high level of patient satisfaction and that patients found this useful and beneficial.[9] A statistically significant HbA1c reduction for patients in the intervention group was achieved with the use of mHealth and phone-based therapies that allow for bidirectional patient-provider contact.[12,20]

Although every method of intervention revealed significant HbA1c improvement, this review found that coaching groups with interactive physicians showed a larger HbA1c reduction than other forms of intervention. Without remote supervision and continued assistance, it is difficult to attain long-term effectiveness. Consequently, long-term follow-up is crucial for elderly diabetic patients.[21]

Based on the data on the average age of the diabetes mellitus patients, diabetes mellitus itself is more common in older people. Because of this, certain patients might have encountered issues utilizing certain applications, such as inputting blood glucose readings to the website or gaining access to online learning resources. A study shows that elderly patients need time to become familiarized with the mHealth system. However, following self-training and remote help from the medical team, the patients began using the portable smart gadget independently, which resulted in favorable outcomes.[21]

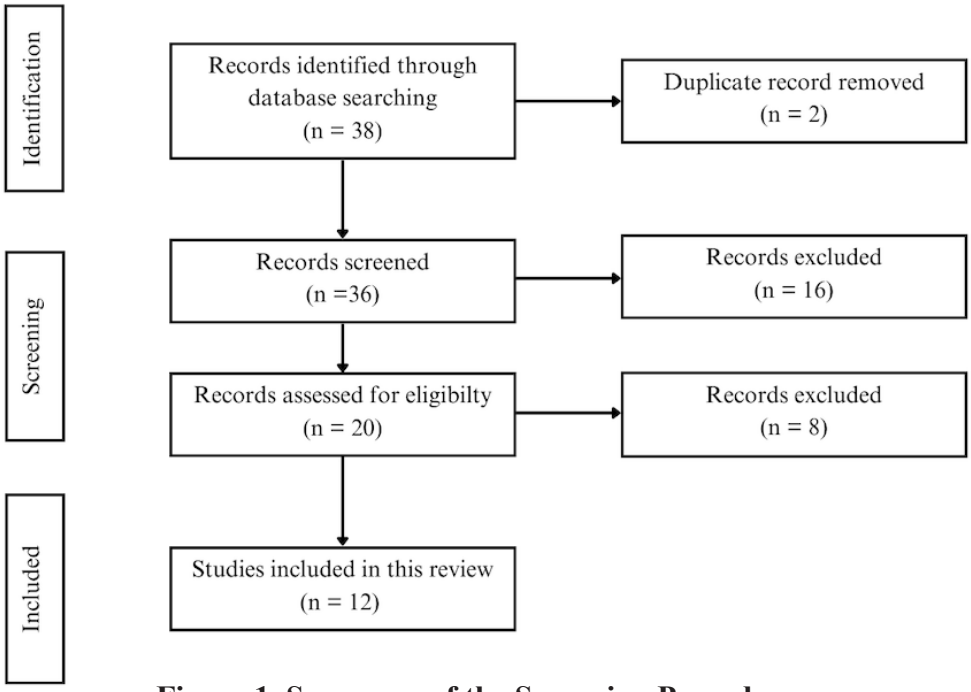

Figure 1. Summary of the Screening Procedure

Patients who underwent a 3 to 6-month intervention showed a greater decrease in HbA1c. These data showed that mHealth intervention might help with HbA1c management for at least 6 months.[2,19,20,22] A prior study revealed similar findings, indicating that 6 months of digital healthcare intervention significantly decreases HbA1c levels in diabetes mellitus patients.[23] mHealth allows patients to get remote diagnosis, therapy, and consultation while also lowering medical costs and preventing cross-infection during outpatient appointments.[24–26]

Liu et al explored the impact of participants' educational backgrounds on the decrease in HbA1c levels, noting a correlation with involvement in mobile peer support. The most actively engaged group predominantly consisted of individuals with at least a college education. This observation suggests that participants with higher educational levels might possess more positive attitudes toward utilizing mobile apps for diabetes self-management and demonstrate a more favorable response within mobile communities.[27]

The Welltang application introduced a team of external medical experts who engage with patients online and offer thorough guidance. Findings indicated that, following a six-month follow-up, the group receiving assistance from the external medical team exhibited notably lower HbA1c levels compared to other groups. This implies that combining app-based self-management with the support of a professional medical team can enhance the management of blood sugar and lipids. Interactive management models, like this one, have the potential to be a significant driving force in the future of diabetes management.[28]

The Wellthy CARE mobile app program implemented a digital persuasion model that concentrated on boosting patient motivation, easing the difficulty of task completion, and offering appropriate incentives to encourage

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action. The program provided coaching in seven key areas: promoting healthy eating, increasing physical activity, enhancing self-monitoring, ensuring medication adherence, fostering problem-solving skills, reducing risk factors, and promoting healthy coping mechanisms.

These areas were tailored to the individual's entered data and were informed by prior clinical, lifestyle, and behavioral information. Participants utilizing the digital therapy for 16 weeks experienced a reduction of 0.49% in HbA1c levels. Furthermore, a correlation was observed between increased program participation and notable decreases in HbA1c levels.[29]

The ¡Sí, Yo Puedo! program, designed for adults with Type 2 Diabetes, resulted in a noteworthy enhancement of diabetes self-efficacy and indicated a potential improvement in HbA1c levels within the treatment group after 6 months, compared to the control group. The program's success in maintaining high attendance and low attrition could be attributed to intervention elements such as customizing content to the local context, reinforcing information and motivation through methods like text messages, group sessions, and follow-up phone calls led by class leaders. The significance of group-based session attendance as a moderator of program effectiveness was underscored. Additionally, participants in the treatment group exhibited a substantial increase in diabetes self-efficacy, potentially acting as a mediating factor contributing to the observed improvement in HbA1c levels. [19]

Conclusion

This research found 12 articles that reported the findings of RCTs of mHealth for patients with type 1 and 2 DM patients. In general, this study concluded that mHealth interventions improve HbA1c in diabetes mellitus patients considerably. Our study's limitations include the fact that every outcome and most subgroups show notable heterogeneity. The intricacy of telemedicine treatments—including the duration, strategies, combinations, and quality of mobile applications—may be a factor in the variance. Second, we found that research number limitations put doubt on the effectiveness of self-care outcomes. For future research, further studies with bigger sample sizes and data on the results of self-care are needed.

It is suggested that more research be performed on the relationship between various intervention strategies and their constituent parts. The views and perspectives of patients regarding the physical characteristics and design aspects of different interventions—mobile applications, texts, and phone calls—need to be further investigated. Future research must address the elements affecting mHealth's acceptance and utility after examining patients' opinions about its use. It is essential for their impact and application in clinical practice that these therapies are evaluated based on their cost-effectiveness factor.

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Table 1. Characteristic of the Included Studies

Authors	Years	Diabetes Mellitus Type	Study				Participants				Methods	Findings
			App	Control	Interventions (n)	Control (n)	Age (Years, mean % and SD)	Gender (%)	Duration of Diabetes Mellitus (years, mean % and SD)	Ethnic Groups		
Liu et al[27]	2022	T1D	TangTang-Quan	N/A	693	N/A	3 Intervention; 1.00 ± 9.50	Intervention; Male = 33.90, Female = 66.10	Intervention: 8.30 ± 6.80	Chinese	The change in mean fasting blood sugar (FBG), postprandial blood sugar (PBG), and glycosylated hemoglobin (HbA1c) from baseline to the 12th month was evaluated.	HbA1c among the 693 people improved in the 12th month.
Tack et al[30]	2018	T1D	Mobile app	N/A	19	N/A	Intervention; 43.80 ± 14.10	Intervention; Male = 36.84; Female = 63.15	Intervention: 22.80 ± 14	Dutch	Adults with diabetes mellitus attempted the app for six weeks and their HbA1c were evaluated through surveys.	The patient's hemoglobin A1c dropped from 7.9% to 7.6% after six weeks.
Ryan et al[31]	2017	T1D	Intelligent Diabetes Management	N/A	18	N/A	Intervention; 40 ± 13.90	Intervention; Male = 27.78; Female = 72.22	Intervention: 27.3 ± 14.90	Caucasian	The participant's diabetic regimens were entered on the synchronized IDM website after the app had been downloaded by the patients. Their data were examined online at 2, 4, 8, 12, and 16 weeks during the active period, and feedback was given electronically. The glycated hemoglobin (A1C) level change was the main outcome.	The median HbA1C value decreased from 8.10% to 7.80%.

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			App	Control	Interventions (n)	Control (n)	Age (Years, mean % and SD)	Gender (%)	Duration of Diabetes Mellitus (years, mean % and SD)	Ethnic Groups		
Zhang et al[32]	2019	T1D and T2D	Welltang	Patients received standard care and did not download Welltang on their smartphone.	184	92	Intervention; App Self Management Group: 52 ± 10, App Interactive Management Group: 52 ± 12 Control: 55 ± 11	Intervention; App Self Management Group: Male = 64.10, Female = 35.90, App Interactive Management Group: Male = 59, Female = 41 Control; Male = 62.80, Female = 37.20	Intervention: App Self Management Group = 11.20 ± 5.60, App Interactive Management Group = 10.10 ± 5.50 Control: 12.70 ± 7.10	Chinese	This study was a 6-month long and change in glycated hemoglobin (HbA1c) level was the main result.	At months six, the HbA1c levels of patients in the app interactive management group were considerably lower than those in the app self-management and control group.

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			App	Control	Interventions (n)	Control (n)	Age (Years, mean % and SD)	Gender (%)	Duration of Diabetes Mellitus (years, mean % and SD)	Ethnic Groups		
Potter et al [9]	2022	T2D	*GLOOK!* app	N/A	15	N/A	54.07	Intervention; Male = 73.33, Female = 26.66	N/A	Australian	The patients used a glucose monitor and an Apple Watch to sensor patient's behavior, food intake, medication, and insulin use for 12 days. The submitted data were linked into the *GLOOK!* software on the patients' smartphones. Participants were also interviewed at both the beginning and end of the study to evaluate their acceptance of the intervention and its potential impact on promoting positive behavior change.	The HbA1c level was reduced by 0.22% in 12-day research. The *GLOOK!* system received excellent feedback from patients, such as the patients were excited in continuing to use the app system if some usability and reliability issues were addressed and felt that adopting the method encouraged long-term behavior improvements.
Koot et al [33]	2019	2019	GlycoLeap	N/A	100	N/A	53.50	Intervention; Male = 53, Female = 47	Intervention: 8.80	Chinese 45, Malay 29, Indian 18 and another ethnicity 8	Participants were accessed to GlycoLeap and completed a survey during the follow-up to assess self-reported changes in diabetic self-care, nutritional consumption, physical activity, program participation, and user satisfaction after ≥12 weeks.	HbA1c improvements were clinically significant in the intervention group.

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Xu et al [12]	2019	2019	EpxDiabetes	No provider-initiated follow-up based on the self-reported FBG data.	33	32	Intervention: 54.60 ± 1.82 Control: 55.34 ± 1.94	Intervention; Male = 37.50, Female = 62.50 Control; Male = 25, Female = 75	N/A	Intervention: Caucasia = 6, African American = 27 Control; Caucasian = 2, African American = 29	EpxDiabetes automated phone calls or text messages were used to obtain self-reported FBG data. Only responses from the intervention groups were shared with providers, enabling follow-up and bidirectional contact.	After 6 months, HbA1c levels were measured. The intervention group had an absolute HbA1c drop of 0.69% whereas the control group had a reduction of 0.03%.
Krishnakumar et al [29]	2021	2021	Wellthy CARE mobile app	N/A	102	N/A	50.80	Interventions; Male = 68.60, Female = 31.40	N/A	Indian	Patients used Wellthy CARE mobile app to track meals, weight, physical activity, and blood sugar levels. They also received lessons, feedback from an artificial intelligence-powered chatbot, and periodic interactions with certified diabetes mellitus educators via voice calls and chats. The study included pre- and post-intervention HbA1c measurements.	The average change in HbA1c after 16 weeks was - 0.49%. 63.70% of all patients had improved HbA1c readings, with a mean change of 1.16%.

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			App	Control	Interventions (n)	Control (n)	Age (Years, mean % and SD)	Gender (%)	Duration of Diabetes Mellitus (years, mean % and SD)	Ethnic Groups		
Alanzi et al [34]	2018	2018	Saudi Arabia Networking for Aiding Diabetes system (SANAD system)	Usual medical treatment and management by the health care staff of medical center.	10	10	Intervention: 18-40 years = 80, 41-50 years = 20 Control: 18-40 years = 70, 41-50 years = 30	Intervention; Male = 80, Female = 20 Control; Male = 70, Female = 30	Intervention: ≤ 5 years = 80, 6-10 years = 20 Control: ≤ 5 years = 100	Arabian	The blood glucose sensors were activated and operated by the intervention group using the SANAD system, and the information was sent via the SANAD app for smartphones, using the provided phone. On the other hand, those in the control group were managed by medical center staff and got regular medical therapy. The HbA1c levels of the participants were measured both at enrollment and six months later during the study.	SANAD system among Saudi type 2 diabetes mellitus participants successfully reduced HbA1c levels.
Kim et al [20]	2018	2018	mDiabetes	Record measured glucose levels at the same frequency as the intervention group and continue using the method of	90	82	Intervention: 60 ± 8.40 Control: 56.70 ± 9.10	Intervention: Male = 55.60, Female = 44.40 Control: Male = 47.60, Female = 52.40	Intervention: 13.20 ± 8.00 Control: 12.50 ± 7.30	South Korean	This trial was a 24-week clinical trial. The mDiabetes app and its integration with the activity tracker and glucometer were demonstrated to the intervention group. The insulin dose algorithm recommended by the mDiabetes system was to be followed by those who were in the mDiabetes group. The difference between the baseline and 24-week HbA1c values was the primary outcome. The other	After 24 weeks, the intervention group's HbA1c level drop from baseline was larger than the control group's.

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Authors	Years	Diabetes Mellitus Type	Study				Participants				Methods	Findings
			App	Control	Interventions (n)	Control (n)	Age (Years, mean % and SD)	Gender (%)	Duration of Diabetes Mellitus (years, mean % and SD)	Ethnic Groups		
Kim et al [20]	2018	2018	mDiabetes	Record measured glucose levels at the same frequency as the intervention group and continue using the method of insulin dose adjustment previously indicated by their physician and nurses.	90	82	Intervention: 60 ± 8.40 Control: 56.70 ± 9.10	Intervention: Male = 55.60, Female = 44.40 Control: Male = 47.60, Female = 52.40	Intervention: 13.20 ± 8.00 Control: 12.50 ± 7.30	South Korean	This trial was a 24-week clinical trial. The mDiabetes app and its integration with the activity tracker and glucometer were demonstrated to the intervention group. The insulin dose algorithm recommended by the mDiabetes system was to be followed by those who were in the mDiabetes group. The difference between the baseline and 24-week HbA1c values was the primary outcome. The other markers including the difference in HbA1c values from baseline after 12 weeks were secondary end goals.	After 24 weeks, the intervention group's HbA1c level drop from baseline was larger than the control group's.
Whittemore et al [19]	2020	2020	*¡Sí, Yo Puedo Vivir Sano con Diabetes!*	The control group were provided usual T2D care at The Seguro	26	21	Intervention: 53.90 ± 9.20 Control:	Intervention; Male = 34.60, Female = 65.40	Intervention: 10.20 ± 7.20 Control: 13.50 ±	Mexican	Participants in the intervention group were given the *¡Sí, Yo Puedo* program which featured seven interactive group-based diabetic self-management educative sessions. The program consisted of daily text/picture	There was a tendency toward decreasing HbA1c at 6 months in the treatment group compared to the control group.

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Table 2. . Trial Results According to HbA1c (%) Values

Authors	Years	Diabetes Mellitus Type	Study				Participants				Methods	Findings
			App	Control	Interventions (n)	Control (n)	Age (Years, mean % and SD)	Gender (%)	Duration of Diabetes Mellitus (years, mean % and SD)	Ethnic Groups		
Whittemore et al [19]	2020	2020	*¡Sí, Yo Puedo Vivir Sano con Diabetes!*	The control group were provided usual T2D care at The Seguro Popular clinic.	26	21	Intervention: 53.90 ± 9.20 Control: 56.80 ± 8.30	Intervention; Male = 34.60, Female = 65.40 Control; Male = 30, Female = 70	Intervention: 10.20 ± 7.20 Control: 13.50 ± 7.30	Mexican	Participants in the intervention group were given the *¡Sí, Yo Puedo* program with seven interactive group-based diabetic self-management educative sessions. The program consisted of daily text/picture messages which were sent out daily for 6 months. Data on primary (HbA1c) and secondary (clinical, psychosocial, and behavioral) outcomes were gathered at baseline, 3 months, and 6 months.	There was a tendency toward decreasing HbA1c at 6 months in the treatment group compared to the control group.
Di Molfetta et al [22]	2022	2022	Glucoonline TM system	Patients were provided with a typical glucose meter and they were instructed to record their glucose readings on a paper diary.	62	61	Intervention: 47.15 ± 14.54 Control: 45.21 ± 14.76	Intervention; Male = 53.20, Female = 46.80 Control; Male = 55.70, Female = 44.30	Intervention: 32.85 ± 15.36 Control: 30.63 ± 15.41	N/A	The experimental group received a smartphone-connected meter and a smartphone with software-implemented real-time data transmission. Web-based electronic GlucoonlineTM enables numerous assessments is available. Participants in the control group were provided with a standard glucose meter and asked to record their glucose readings on a paper diary. Change in HbA1c from Visit 1 measured at Visit 3 was the main outcome.	In comparison to standard of care, the use of the GlucoonlineTM system led to a 0.38% decrese in HbA1c in patients with insulin-treated type 2 diabetes mellitus from baseline and a larger percentage of patients meeting a HbA1c goal level of less than 7%.

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Conflict of Interest
None declared.

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