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ΣΥΣΤΗΜΑΤΙΚΗ ΑΝΑΣΚΟΠΗΣΗ

Αποτελεσματικότητα των εφαρμογών για κινητά σε ενήλικες με διαβήτη τύπου 2 στο γλυκαιμικό έλεγχο: μια συστηματική ανασκόπηση τυχαιοποιημένων ελεγχόμενων δοκιμών

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ΠΕΡΙΛΗΨΗ

Εισαγωγή: Ο αυξανόμενος παγκόσμιος επιπολασμός του σακχαρώδη διαβήτη κατέστησε αναγκαία την εφαρμογή έγκαιρων παρεμβάσεων για τη διαχείριση του. Η έλευση αρκετών τεχνολογικών εξελίξεων και ιδιαίτερα της κινητής τηλεφωνίας έχει θεωρηθεί ότι παρουσιάζει μεγάλες δυνατότητες για την παροχή γρήγορων και οικονομικά αποδοτικών παρεμβάσεων σε ασθενείς με διαβήτη.

Σκοπός: Η παρούσα μελέτη στοχεύει να διερευνήσει την αποτελεσματικότητα των παρεμβάσεων που βασίζονται σε εφαρμογές για κινητά σχετικά με την επίτευξη του γλυκαιμικού ελέγχου μεταξύ ενηλίκων με Σακχαρώδη Διαβήτη Τύπου 2 (ΣΔΤ2). **Μεθοδολογία**: Πραγματοποιήθηκε βιβλιογραφική ανασκόπηση στις ηλεκτρονικές βάσεις δεδομένων PubMed και Scopus. Τα κριτήρια εισαγωγής περιλάμβαναν τυχαιοποιημένες ελεγχόμενες δοκιμές (RCT) που ερευνούσαν παρεμβάσεις που βασίζονται σε εφαρμογές για κινητά σε ενήλικες ασθενείς με ΣΔΤ2, ενώ το κύριο αποτέλεσμα που ερευνήθηκε ήταν η αξιολόγηση των αλλαγών στα επίπεδα γλυκοζυλιωμένης αιμοσφαιρίνης A_{1c} (HbA_{1c}). Οι μελέτες αφορούσαν την τελευταία 10ετία και ήταν στην αγγλική ή την ελληνική γλώσσα. **Αποτελέσματα**: Με την εφαρμογή των κριτηρίων εισαγωγής πραγματοποιήθηκε πρόσβαση σε 181 RCT μελέτες με πλήρες κείμενο. Από αυτές, οι 12 μελέτες πληρούσαν τα κριτήρια εισαγωγής στην παρούσα μελέτη και περιλάμβαναν 2.533 ασθενείς με ΣΔΤ2, όπου οι παρεμβάσεις βασίζονταν σε εφαρμογές μέσω κινητού. Βρέθηκε ότι οι παρεμβάσεις ήταν αποτελεσματικές στην απόκτηση γλυκαιμικού ελέγχου όσον αφορά τη μείωση της HbA_{1c} και τη βελτίωση πολλών άλλων δευτερογενών αποτελεσμάτων, όπως η αυτοδιαχείριση, η ποιότητα ζωής και η επίγνωση της νόσου. **Συμπεράσματα:** Η χρήση των εφαρμογών mHealth φαίνεται να είναι αποτελεσματική στον γλυκαιμικό έλεγχο των ασθενών με διαβήτη, όπως φαίνεται από τη μείωση των επιπέδων HbA_{1c}. Απαιτούνται περαιτέρω μελέτες, προκειμένου να αξιολογηθεί ο αντίκτυπος τέτοιων εφαρμογών στη φροντίδα του διαβήτη μακροπρόθεσμα και η δυνατότητα τους να υποστηρίξουν διαφορετικούς πληθυσμούς παγκοσμίως.

Λέξεις Κλειδιά: Σακχαρώδης διαβήτης τύπου 2, εφαρμογές για κινητά, αυτοδιαχείριση, γλυκοζυλιωμένη αιμοσφαιρίνη A_{1c}, αυτοέλεγχος της γλυκόζης του αίματος.

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SYSTEMATIC REVIEW

Effectiveness of mobile apps on glycemic control in adults with type 2 diabetes: a systematic review of randomized controlled trials

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ABSTRACT

Introduction: The rising global prevalence of diabetes mellitus has necessitated the implementation of prompt interventions to manage diabetes. The advent of several technological developments and especially mobile technology has been assumed to present great potential to deliver prompt and cost-effective interventions for patients with

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diabetes.
Aim: The present study aims to investigate the efficacy of interventions based on mobile apps in terms of glycemic control attainment among adults with type 2 Diabetes Mellitus (T2DM).
Methodology: A research was constructed on online database PubMed and Scopus. Inclusion criteria were included randomized controlled trials (RCTs), investigating mobile app-based interventions among adult patients with T2 DM, whilst the main outcome investigated was the assessment of the changes in glycosylated Hemoglobin A_{1c} (HbA_{1c}) levels.
Results: By applying the eligibility criteria 181 RCTs with full text. Across them 12 trials met the inclusion criteria for the present study and involved 2.533 patients with T2 DM, where the interventions were based on mobile applications. These app-based interventions were found to be efficient in obtaining glycemic control in terms of lowering HbA_{1c} and improving several other secondary outcomes including self-management, quality of life and disease awareness.
Conclusions: The usage of mobile health (mHealth) applications seems to be efficient in glycemic control of patients with diabetes as shown by the reduction of HbA_{1c} levels. Future studies are needed, in order to evaluate the impact of such applications on diabetes care in the long term and their potential to support more diverse populations worldwide.

Keywords: Type 2 Diabetes Mellitus, mobile apps, self-management, glycosylated Hemoglobin A_{1c}, self-monitoring of blood glucose.

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INTRODUCTION

The continuous increase in the worldwide burden of type 2 Diabetes Mellitus (T2DM) indicates that diabetes constitutes a public health issue that has reached pandemic proportions, as according to estimates approximately 9% of the global population will probably be diagnosed with T2DM by 2035[1]. As the T2 DM prevalence increases health systems will face great pressures in terms of the appropriate management of patients with diabetes and the avoidance of diabetic complications including macro and microvascular complications and premature death[2,3]. Diabetes is an independent risk factor for several cardiovascular diseases and has been widely associated with high rates of mortality from stroke, ischemic heart disease etc., as well as other non-cardiovascular diseases such as infections[4,5]. Hence, it becomes evident that the steady achievement of target levels of a multitude of risk factors obesity, hypertension, hyperglycemia and dyslipidemia included, is of paramount importance[6].

Upon the establishment of the diabetes diagnosis, lifetime self-management of the disease is crucial to glycemic control and is correlated with the patients' with diabetes prognosis in the long term[5,7]. Self-management of diabetes entails the self-monitoring of blood glucose levels, lifestyle modifications including healthy eating habits, smoking cessation, physical activity and weight management, pharmacologic interventions, active participation in the prevention of diabetic complications, as well as self-selected behavioral goal-setting[5]. There is evidence[8] that patient education may improve diabetes self-management, diabetes-

related knowledge, patients' quality of life and education, enhanced glycemic control, whereas reducing healthcare costs. Nevertheless, it is only a small fraction of patients, who receive such education[9], whilst adherence has been indicated to be poor[10].

Despite T2 DM is a lifestyle-related disease requiring self-management on a daily basis[11], current management practices principally depend on in-person interviews conducted at outpatient clinics and pharmacologic treatment. Therefore, maintaining constant care on a daily basis may prove to be a rather challenging endeavor for patients with diabetes[3]. Furthermore, such face-to-face education programs are resource intensive. Several advancements in mobile technology may present great important potential in terms of delivering effective self-management support that is not only convenient but also may prove to be cost-effective[12,13].

In this light, mobile health technology provides opportunities to resolve the issue of providing uninterrupted and continuing care for patients suffering from chronic illnesses, including DM[14]. The adoption of the mHealth strategy as a public health practice in the field of for chronic illness monitoring is estimated to gain significant momentum in the years to come due to the increased health expenditures to meet the needs of an aging population and the sharp increase in chronic diseases prevalence and comorbidity[15]. Diabetes self-management education based on mobile applications has been considered to be a pioneering option, in that it abolishes location and time barriers and simultaneously offers real-time personalized medical treatment[16,17]. Smartphone apps have the advantage of being convenient, global, cost-effective and highly interactive. In contrast with traditional Web and computer-based telemedicine interventions[18,19], mobile apps may prove rather beneficial in diabetes management[20]. They allow healthcare professionals (HCPs) to assess the patient remotely and proceed to the prompt intervention between visits, and particularly in urgent situations including severe hyperglycemia or hypoglycemia[21]. Several studies[17,22–24] have provided evidence that mHealth solutions are and improve glycosylated HbA_{1c} levels and henceforth can be utilized as an adjuvant approach to managing diabetes. The findings of several meta-analyses[21,25] have shown that their use can lead to a 0.5% decrease in HbA_{1c} levels, with the reduction being more prominent when combined with feedback by HCPs.

AIM

The aim of this study was to provide a summary of the scientific evidence regarding the effectiveness of mobile apps in terms of glycemic control among adults with type 2 diabetes mellitus of randomized clinical trials.

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METHODOLOGY

Study Design

A systematic review was conducted to summarize the existing evidence of the mobile app-based interventions in glycemic control among adults with type 2 diabetes.

Data sources & Searches Strategy

A systematic review was conducted. We searched for RCTs on online databases PUBMED/MEDLINE and Scopus with Full Text using the terms “Diabetes 2 type” OR “T2DM” AND “mobile apps” AND “mobile Health” OR "mHealth” AND “self-management” AND “glycosylated Hemoglobin A_{1c}” OR “HbA_{1c}” AND “self-monitoring of blood glucose”. The time period screened was January 1, 2016, to December 12, 2021.

Study Inclusion & Exclusion Criteria

Subsequent to the comprehensive search of the literature, the titles and abstracts of selected studies were screened by 2 independent assessors who selected the studies to be included. The reviewers independently conducted the research and then screened the title, the abstract and the full text for eligibility. If this was not possible the full text was read to determine the eligibility of the study. Any disagreements that were created between those reviewers were resolved through discussion.

The selected RCTs were those that made a comparison between mobile app-based interventions with standard care in adult patients with diabetes. Mhealth applications were mobile apps installed in smart mobiles and provided real-time interaction with their users. The primary outcome investigated was the changes observed in the levels of glycosylated Hemoglobin A_{1c} (HbA_{1c}) concentration when compared to baseline.

The studies excluded were those not being Randomized Controlled Trials (RCTs), or those who were study protocols and pilot studies. Trials that did not evaluate HbA_{1c} concentration were also excluded. Studies whose participants were children or adolescents were excluded, since these patient’s populations require distinctive therapeutic approaches and necessitate a stricter or a more complex glycemic control. Studies that utilized applications for either continuous glucose monitoring (CGM) or continuous subcutaneous insulin infusion (CSII) were also excluded, as these applications natures resembles to that of medical devices.

Data extraction

Data from the studies selected were extracted by 2 reviewers and outlined in the **Table 1**. The following data were extracted from each study were authors, year of publication, study design and population, information related to intervention and outcomes was extracted too. Any disagreements between the 2 reviewers were resolved through discussion.

The following flowchart **Figure.1** presents the selection strategy method, according to which the articles were separated into selection stages, leading up to the selection of the trials that were finally included in the systematic review.

RESULTS

By using the search terms and by applying the eligibility criteria 181 RCTs with full text were accessed and screened. At the initial phase, 45 trials were excluded following the assessment of their title and 39 duplicates trials were found and removed. Further, 33 trials were excluded after evaluating their abstract. The full texts of 64 studies were evaluated, of which 52 were excluded on the basis that they did not meet the eligibility criteria. More specifically, 13 and 7 studies were excluded on the grounds of being study protocols and pilot studies, respectively. In the case of 13 trials the participants were adolescents or patients with diabetes T1, and hence these studies were not included in the review. Furthermore, 3 trials did not assess app-based interventions, but rather investigated other web or telemedicine-based interventions. Finally, 4 studies did not investigate the primary outcome, namely did not involve an evaluation of glycemic control in terms of glycosylated Hemoglobin A_{1c} concentration (%) from baseline and hence were not included. Consequently, 12 RCTs were included. In the final stage of the review, the references of the selected trials were searched for further RCTs that could be included in the review.

In the 12 RCTs that were included in the systematic review 2.533 patients with T2 DM participated. 10[2,3,22,26–32] trials investigated the effectiveness of app-based interventions in glycemic control among patients with diabetes. One RCT[33] assessed the efficacy of mobile-app based self-management education for diabetes, as well as the impact of voluntary participation on its effectiveness. One RCT[34]involved an intervention comprising of a mHealth App and a chest-wearable band to monitor exercise. Across 12 trials, 5 RCTs were conducted in China[22,27,29,30,34], 1 in India[32], 2 in Korea[3,34], 1 in Canada[2], 1 in Singapore[28], 1 in Sri Lanka[3] and 1 in Iceland[35].

A randomized control trial study was conducted by Kumar et. al.[32] using a smartphone application called DIAGURU, focusing on lifestyle modification and medication management and was used for 6 months among patients with T2 DM. The intervention group consisted of 150 participants who used the app instead of the control group (n=150) with standard care. The intervention group showed better glycemic control while control group showed an increase in HbA_{1C} levels (p=0.001) after 6 months.

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Jia et al.[30] conducted a cluster RCT, with the scope to define the impact of a mobile app-based digital platform named ROADMAP and its effectiveness on diabetes control to assess the HbA_{1c} levels. They found out an improvement of HbA_{1c} control rate by 7.0% to intervention group (n=576). Secondary outcomes were changes with higher control in blood Pressure (BP), low-density lipoprotein cholesterol (LDL-C), fasting blood glucose (FBG) to control group rather than control group with usual care (n=288). There were no findings on hypoglycemia episode and weight gain between the control and intervention groups.

Li et al.[34] involved in their prospective, multicenter RCT an intervention comprising of a mHealth fitness app and a chest-wearable band, so as to explore their efficiency in remotely controlling exercise of patients with diabetes. In the intervention group participants watched exercise videos on the app and wore a chest band (n=51), whilst in the control group (=50), participants were required to self-report their exercise (heart rate, duration, exercise duration). Despite patients with diabetes in the intervention group improving their endurance (p=0.02) and body fat percentage (p=0.01), no significant difference was found in terms of glycemic control. Yet more participants receiving the intervention ceased antidiabetic medication or had their dosage lowered.

Lim et al.[28] conducted a multicenter RCT, with the scope to define the impact of a mobile app usage on metabolic outcomes, as well as weight management in adults with T2 DM. 204 participants received sessions with a registered dietitian with regards to diet and physical activity. The control intervention group (n=99) had to utilize the mobile for a six-month period and track food intake and physical activity daily twice in a week, as well as utilize the app to communicate with the research dieticians on a regular basis. The group that received the intervention showed a significant decrease in glycosylated HbA_{1c}, whilst a greater proportion of participants within the intervention group having their diabetic medication reduced at 6 months. The greater HbA_{1c} decrease was observed among participants with HbA_{1c} levels of ≥ 8% (p = 0.001).

The prospective, multicenter RCT carried out by Lee et al.[33] to investigate the efficacy of self-management education for diabetes based on a mobile app, as well as the impact of voluntary participation on its efficacy. Out of 72 participants, 31 received usual care, while the rest received mHealth-based education for diabetes management in tandem with regular personalized feedback from HCPs. The primary outcome assessed was the glycated hemoglobin (HbA_{1c}) levels over 6 a six-month period and secondary outcome included changes in BMI, blood

pressure and lipid profile, self-care knowledge, quality of life and problematic areas in the disease. Over 6 months HbA_{1c}, total cholesterol levels and Problem Areas in Diabetes scores showed a significant reduction (p=0.04, p=0.04 and p=0.02, respectively). Moreover, total diet (p=0.03) and self-monitoring of blood glucose (p=0.01) showed a significant increase in the intervention group.

The cluster multicenter RCT undertaken by Yang et al.[3] investigated the clinical efficacy and applicability of a diabetes management system based on an app within primary healthcare settings. 97 participants (control group) were allocated to outpatient in-person consultation with a physician, while 150 patients received the intervention that included faced-to-face consultations plus the usage of a mobile app for self-monitoring of blood glucose (SMBG) for 3 months. At 3 months, the intervention was correlated with a significant improvement in HbA_{1c} levels (p=0.003) and fasting plasma glucose (p=0.005), whilst secondary outcomes such as blood pressure, treatment satisfaction and medication adherence motivation were also significantly improved. The effect of the management system on glycemic control was more profound among patients, who were younger and poor glycemic control at baseline.

The objective of Zhai & Yu's[27] RCT was to examine whether a diabetic management app could be efficient in diabetes management self-efficacy and glycemic control in the patients of a Chinese community hospital. 60 out of 120 enrolled patients received the mobile app intervention (n=60) additionally to usual care, whilst the rest (control group, n=60) received usual care for a 6-month observation. 3-month and 6-month follow-ups were conducted. The results indicated that at the end of the trial, patients in the intervention group had improved their HbA_{1c} levels ($p<0.05$) and bettered their self-efficacy scores ($p<0.05$).

Hilmarsdottir et al.[35] conducted a randomized control study with two parallel group where participants were randomly selected to the intervention group (n=15) with the SidekickHealth smartphone app and control group (n=15) with standard care. There were found no significant difference in glycemic control between these two groups and also no significant changes were observed within the control group over the research period. But they found in the intervention group a statistically significant decrease in HbA1c levels, in diabetes distress by using the instrument Problem Areas in Diabetes Scale (PAID), and in anxiety symptoms by using the instrument Hospital Anxiety and Depression Scale (HADS) ($p<0.05$).

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Agarwal et al.[2] conducted a multicenter pragmatic RCT investigating whether the usage of a mobile app called BlueStar, a virtual diabetes management coaching application, could lead to the improvement of HbA_{1c} levels among a wide array of T2 DM patients in real-life clinical context. The intervention group consisted of 110 participants, who utilized the app for 6 months, whilst the control group consisted of 113 patients that were randomized to the waiting list for 3 months, whilst receiving standard care and then utilized the app for the remaining. The primary health outcome assessed was glycemic control and especially the changes in by HbA_{1c} levels at 3 months. The secondary outcomes that were evaluated included the app usage impact on diabetes self-efficacy, quality of life and experience for care. The findings did not provide any evidence of app usage impacting HbA_{1c} levels (p=0.19), or other secondary health outcomes.

Gunawardena et al.[26] aimed to investigate the effectiveness of a mobile-based app "Smart Glucose Manager" utilization in diabetes management. The app includes several features including reminders addressed to users to check their glucose, exercise, take their medication punctually etc. From 67 patients included, 35 were randomized to utilize the app, while 32 proceeded with their usual care. According to the findings, at 6-month follow up, the mobile app intervention group showed a significant decline in A_{1c} levels ($p < 0.0001$), with this improvement being positively correlated with the application usage ($p < 0.001$).

Wang et al.[29] evaluated the clinical effect of the provision of continuous care for T2DM patients via a mobile health application in comparison with traditional counseling. The eligible 120 participants were randomized (1:1) to use a mobile phone application or to standard care. The glycemic control in terms of HbA_{1c} levels was higher in the group that received the intervention ($p < 0 .05$), while significant improvement related to disease awareness levels, self-management abilities, fast blood glucose and readmission was observed in those patients ($p < 0 .05$)

Yu et al.[22] carried out a non-blinded, randomized trial, aiming to investigate the efficacy of a mobile phone application in combination with or without self-monitoring of blood glucose on glycemic control in individuals diagnosed with T2M. The 185 participants were randomized to receive standard care, SBMG, usage of a mobile-based app and mobile app usage in addition to SBMG. At 24 weeks, patients who managed a < 7% reduction in HbA_{1c} levels were significant more in the groups of the mobile intervention alone or the mobile app plus SBMG in comparison with the other two groups ($p=0.005$ for all). The mobile app intervention

was found to be the principal effective factor for improvement in HbA_{1c} levels (p=0.034).

DISCUSSION

The findings of the current systematic review indicate that, when compared to standard diabetes management models, mHealth in the form of applications-based interventions for diabetes management is correlated with significant improvements in patients' glycemic control as presented by the changes in HbA_{1c} levels, whilst enhancing other equally important outcomes such as patients' awareness, self-monitoring, self-efficacy and quality of life. These findings suggest that patients with T2DM may benefit significantly from mobile-based apps in terms of attaining glycemic control and thus such interventions may be more suitable for long-term diabetes management.

In accordance with the findings[3,22,26–29,33,36], several previous studies evaluating the efficacy of mobile based apps in glycemic control, have shown that indeed mHealth interventions are associated with a reduction in HbA_{1c} levels that is of clinical significance[21,24,36–41]. Moreover, the findings indicate that mHealth is correlated with the improvement of several secondary outcomes including self-monitoring and self-efficacy[27,29,33], disease awareness[29], improved fasting glucose levels[3,29], improved total diet and cholesterol levels[33], decreased readmissions[29], as well the reduction in antidiabetic medication[28,34]. In the same vein, a systematic review and meta-analysis[25] has indicated that mobile-based apps aiming to diabetes management may improve not only HbA_{1c}, but also enhance patients' disease knowledge and lead to lifestyle improvements. Furthermore, several studies have underlined the efficacy if mobile apps in improving other clinical outcomes of diabetes such as diabetes satisfaction, self-care behaviors and self-monitoring[20,31,42].

What should be noted though is that the efficiency of available mobile-based apps and their distribution may vary significantly by their functional design[19,41]. Nowadays, there are numerous diabetes management apps available, reaching up to 1100 applications[19]. From the health-related commercial apps available on Android Google Play and Apple App store the Apple diabetes is among the top-ranking categories, followed by depression and asthma[43,44]. Yet, despite this abundance of mobile-based apps, the available RCTs evaluating their effectiveness in self-management of diabetes are scarce[29,45], indicating that there is a significant absence of evidence to guide patents and clinicians when aiming to choose an effective and more importantly safe application among the plethora of diabetes self-management apps[43–45].

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Another finding suggests that the positive impacts of mobile based application are more profound in the case of patients, who engage with the app voluntarily and utilize it in a more frequent basis[33], suggesting that this characteristic is of paramount importance when aiming to gain a better understanding of the patients, who actually use these apps and what are the app features that increase users' engagement[45] and therefore can prove to provide valuable insight when aiming to target participants for mHealth services in large populations in the future. Of particular concern are those patients with low health literacy, as they tend to obtain poorer glycemic control, whilst being less likely to have computer literacy and utilize health information technology[46].

Despite these concerns, the popularization of smart mobile devices, will undoubtedly popularize the development and use of mobile applications in the field of mHealth that will in turn facilitate medicine practice and particularly in case of continuous care for chronic diseases such as diabetes[47].

LIMITATIONS

The present study faced some limitations. Firstly, only 12 trials were included, a fact that may limit the strength of its findings. Moreover, the follow-up periods of the trials included were short and thus the effectiveness of the diabetes management app usage was not assessed in the long term. Another issue may be the high drop outs in the trials. Second, we examined only 12 trials in our study, which may limit the strength of the findings. Finally, younger patients, who are more familiar with smart phone devices may be more willing to voluntarily enroll in the trials and that may insert selection bias in the trials conducted.

CONCLUSIONS

The usage of mHealth applications seems to be rather efficient in glycemic control of patients with diabetes as shown by the reduction of HbA_{1c} levels. Further studies are needed to evaluate the impact of such applications on diabetes care in the long term and their potential to support more diverse, global patient populations.

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ANNEX

FIGURE 1. Flow chart for study selection stages

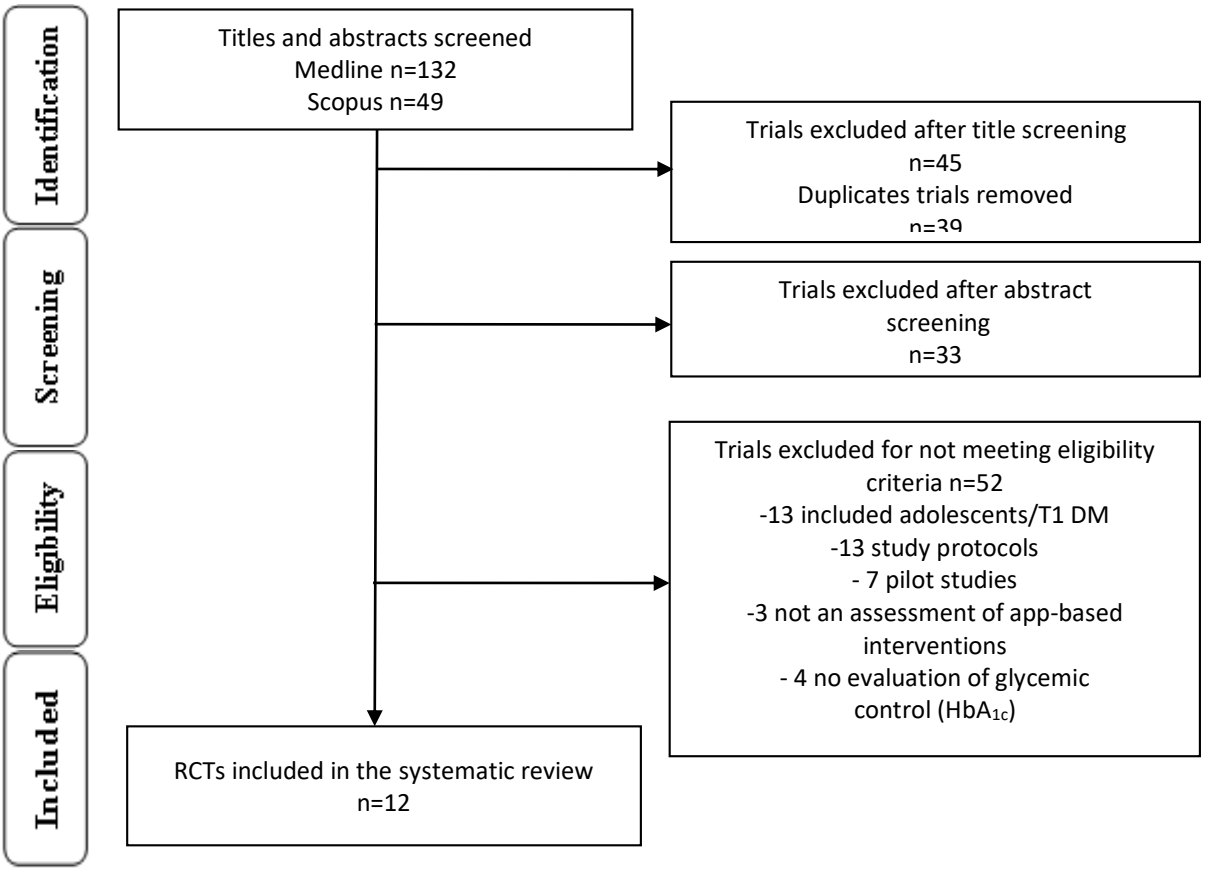

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TABLE 1. Main Characteristics of the 12 studies identified in the Systematic Review.

Authors	Year of Publication	Study Design	Study Population	Intervention	Outcomes
Kumar et al. (India)	2021	RCT	300	• In intervention group participants (n=150) used mobile app for medication management and lifestyle modification • Standard care (n=150)	• Intervention group significant reduction of HbA_{1c} levels (p<0.001) • HbA_{1C} levels were showing a reduction in the study group, and increase in the control group (p=0.001)
Jia et al. (China)	2021	Cluster, RCT	864	• In Intervention group used ROADMAP application with hierarchical diabetes management + website (n=576) • Control group with standard care (n=288)	• In the intervention group showed HbA_{1c} control rate higher than control group about 7.0% at 12-months follow-up • Secondary outcomes changes with higher control in BP, LDL-C, FBG to control group • No difference was found on hypoglycemia episode and weight gain between groups
Li et al. (China)	2021	Prospective, Multicenter RCT	101	• In intervention group participants watched exercise videos on the app and wore a chest band (n=51) • Heart rate, exercise duration, and intensity were self-reported (n=50)	• Intervention group larger increase in cardiopulmonary endurance (p=0.02) and a larger decrease in body fat percentage (p=0.01) • No difference in hemoglobin A_{1c} level reduction between the two groups. Yet more participants in intervention group stopped taking antidiabetic drugs or had lower dosages
Lim et al. (Singapore)	2021	Multicenter RCT	204	• Standard care + smartphone-based lifestyle intervention (n=99) • Standard care (n=105)	• Intervention group significant reduction in HbA_{1c} levels, with a greater fraction having their diabetic medication reduced within 6 months. • Greater HbA_{1c} reduction among participants with HbA_{1c} levels of 8% or higher (p = 0.001)

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Lee et al. (Korea)	2020	Open-label RCT	72	• mHealth-based diabetes self-management education through mobile app & regular personalized feedback from HCP (n=41) • Standard care (n=31)	• HbA_{1c} (p=0.04), total cholesterol level (p=0.04), and Problem Areas in Diabetes scores (p=0.02) significantly decreased • Total diet (p=0.03) & self-monitoring of blood glucose level scores (p=0.01) increased in intervention group
Yang et al. (Korea)	2020	Cluster, Multicenter RCT	247	• Face-to-face & upload of daily self-monitoring of blood glucose (SMBG) using the app (3 months) (n=150) • Face-to-face & standard care (n=97)	• Significant improvement in HbA_{1c} (p=0.003) & fasting plasma glucose (p=0.005) in the intervention group • Effect on glycemic control was more profound among patients, who were younger and had higher baseline HbA_{1c} levels
Zhai & Yu (China)	2020	RCT	120	• Mobile app and conventional care (n=60) • Standard care (n=60)	• At 6-month follow-up, patients in the app group showed better glycemic control (p<0.05) & improved self-efficacy scores (p<0.05)
Hilmarsdottir et al. (Iceland)	2020	RCT, two parallel groups	30	• SidekickHealth smartphone app used by intervention group (n=15) based on healthy behavior, self-monitoring, nutrition, physical activity, and stress management • Standard care (n=15)	• At 6-months follow up no statistically significant difference in glycemic control as between intervention and control group • A statistically significant decrease in HbA1c level, diabetes distress (PAID), and anxiety symptoms (HADS) in the intervention group (p<0.05)
Agarwal et al. (Canada)	2019	Multicenter Pragmatic RCT	223	• BlueStar mobile app for 6 months (n=110) • Wait-list control (WLC) group (3 months wait & 3 months intervention) (n=113)	• No statistically significant difference in glycemic control as measured by HbA_{1c} levels (p=0.19) • No effect on secondary outcomes measuring diabetes self-efficacy, quality of life, and healthcare utilization behaviors
Gunawardena et al. (Sri Lanka)	2019	RCT	67	• App. Smart Glucose Manager (SGM) (n=35) • Standard care	• At 6-month follow up, the SGM group had significant lower A_{1c} levels (p < .0001) • A_{1c} improvement was

				(n=32)	positively correlated with SGM usage (R = 0.81, p < .001).
Wang et al. (China)	2019	RCT	120	• Continuous care based on mHealth application (n = 60) • Standard care (n=60)	• HbA_{1c} levels were lower in the intervention group (p <0 .05) • Significant improvements in disease awareness levels, self-management abilities, fast blood glucose and readmission (p <0.05)
Yu et et al. (China)	2019	Four-arm parallel, Non-blinded RCT	185	• Group A – standard care (n= 47) • Group B – self-monitoring of blood glucose (SMBG) (n=45) • Group C – Mobile App only (n=48) • Group D – Mobile App and SMBG (45)	• At 24 weeks, HbA_{1c} decreased significantly for all patients • Significant differences in the proportions of patients that achieved HbA_{1c} (p < 0.05) • Mobile app intervention was the main effective factor for HbA_{1c} change (p = 0.034)

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