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REVIEW

The effectiveness of mobile application interventions in improving medication adherence among patients with type 2 diabetes mellitus: a systematic review

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Abstract

Aim: Type 2 diabetes mellitus (T2DM) is a global health concern, and medication non-adherence contributes to poor glycaemic control and complications. Mobile applications are a potential strategy to improve adherence, but their effectiveness remains uncertain. This systematic review evaluates the effectiveness of mobile applications interventions in improving medication adherence in patients with T2DM.
Data Sources: A comprehensive search of PubMed, Cochrane Library, and Scopus was conducted.
Study Selection: Studies included were English-language studies published in from 2013–2023. Study quality was assessed using the Mixed Method Appraisal Tool.
Results: Seven clinical studies with 717 participants (median age 54.7 years) were included. All studies showed improvements in adherence, but only four reported statistically significant changes. Among these, three studies also showed significant reductions in haemoglobin A1c (HbA1c) levels, suggesting a positive clinical impact. The studies were generally of high quality.
Conclusion: Mobile applications appear to improve medication adherence in T2DM patients compared to traditional care. However, the specific application features that enhance adherence are unclear due to variations in study designs and small sample sizes. Future research should focus on identifying key applications characteristics, improving usability, and ensuring cost-effectiveness to optimize patient outcomes.

Keywords: adherence, diabetes mellitus, telemedicine, mobile applications, systematic review.

INTRODUCTION

Diabetes mellitus (DM) presents a global health challenge, with its prevalence continually increasing. By 2019, an estimated 460 million individuals were living with DM, projected to rise to 629 million by 2045.[1,2] Type 2 diabetes mellitus (T2DM) management requires a comprehensive strategy, encompassing lifestyle adjustments, medication, consistent monitoring, and health care.[3] However, the complexity of T2DM management often leads to non-adherence to medication, compounded by the emergence of complications.[4,5] Poor medication adherence results in decreased glycaemic control and associated complications.[6]

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Mobile applications, an example of telemedicine, offer various interactive features such as reminders, educational content, and health consultations, aiming to enhance adherence among chronic disorders including T2DM patients.[7–10] However, the effectiveness of this intervention in improving adherence among T2DM patients remains uncertain, leading to underutilisation in the management of diabetes.[11] Hence, the objective of this study is to evaluate the effectiveness of mobile applications in improving medication adherence among patients with T2DM.

METHOD

Study Selection Criteria

The search criteria for study inclusion encompassed English published articles focusing on the efficacy of mobile applications in improving adherence towards

medication among adult patients with type 2 diabetes mellitus. This systematic review was done following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[12] The detailed inclusion and exclusion criteria utilised for the selection of articles are presented in Table 1.

Search Strategy

We systematically searched PubMed, Scopus, and Cochrane Library for relevant articles from 2013–2023. Our search utilised both subject heading and broad keyword strategies to ensure comprehensive coverage of literature. The search strategy was developed to target three key domains: adherence, diabetes, and telemedicine (Table 2). To ensure the effectiveness of the search strategy, the three domains related to the Boolean operator 'AND' while the keywords within each group were connected using the Boolean operator 'OR'.

Study Selection

The process involved storing all identified citations in Mendeley Cite (Elsevier Limited, London, UK) and employing automated methods to remove duplicates. Two authors manually screened and reviewed publications, initially assessing eligibility based on titles and abstracts outlined in Table 2. Articles that did not meet the inclusion criteria or contained exclusion criteria were excluded. Selected articles were then obtained in full text for systematic review. Eligibility was re-evaluated using a checklist, and articles were categorised as included, excluded, or deferred for further discussion.

Table 1 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
1. Published articles on the effectiveness of mobile applications interventions in improving medication adherence among patients with T2DM 2. Population was adult patients with T2DM 3. English language only 4. Published papers from 2013–2023 5. Accessible in full-text	1. Other telemedicine interventions 2. Adherence to self-monitoring, diet, exercise, guidelines, clinical care, and lifestyle

T2DM = type 2 diabetes mellitus.

Table 2 Literature review search strategy

Adherence	Diabetes	Telemedicine
Adherence	Diabetes	Telemedicine
Nonadherence	Type 2 diabetes mellitus	Telehealth
Non-adherence	Type II diabetes mellitus	Telepharmacy
Compliance	T2DM	Mhealth
Noncompliance	Hyperglycemia/ hyperglycaemia	Ehealth
Non-compliance	Glucose intolerance	Mobile application/ applications
		Mobile apps

Deferred articles underwent comprehensive deliberation by the authors, leading to a consensus decision.

Data Extraction and Management

Following verification, two authors (AR and HN) independently extracted data from the included articles. This data encompassed general characteristics such as participant numbers, study settings, designs, mobile application names, mean participant ages, gender distribution, intervention durations, and participant profiles. The risk of bias within these articles was assessed by methodological approaches and various domains, which enabled us to make well-informed judgements. Furthermore, outcomes from studies, including comparator interventions, application functionalities, and findings related to medication adherence and clinical outcomes, were extracted for analysis.

Quality Assessment

The methodological quality of the included studies was evaluated utilising the Mixed Methods Appraisal Tool (MMAT) Version 2018.[13] MMAT is specifically designed to evaluate the methodological quality of studies and is capable of assessing a wide range of study designs, including qualitative, randomised controlled trials, non-randomised, quantitative descriptive, and mixed methods studies.[14]

In this section, five standards for methodological quality were assessed. Each standard provides three choices of response: 'Yes' (indicating fulfilment of the standard), 'No' (indicating the standard is not met), and 'Unclear' (suggesting insufficient information in the paper to make a judgement). Studies were categorised based on the number of 'Yes' responses received: ≤2 indicated low quality, 3 indicated moderate quality, and ≥4 indicated high quality.[15]

RESULTS

Identified and Included Studies

The PRISMA flowchart depicts the systematic process of paper identification, screening, and final inclusion. Initially, 1205 articles were identified through searching, of which 946 were screened after eliminating duplicates, resulting in 919 exclusions. Full-text retrieval ensued, with only one article proving unretrievable. Out of 28 full-text articles assessed for eligibility, seven met the inclusion criteria. The primary reason for exclusions was that the studies did not evaluate participants' medication adherence, which diverged from the study's specific aims. Additionally, some were excluded for lacking specification regarding the chronic disease under study, such as diabetes type. Further insights into the exclusion reasons are provided in Figure 1.

Characteristics of Included Studies

Table 3 presents data from seven studies, encompassing a total of 717 participants. The median sample size was 93.5 individuals, ranging from 17 to 220. The participants' ages spanned from 48 years to 64 years, with a median age of 55 years. The percentage of female participants varied from 30% to 55%, with an average of 44% across all studies. All studies concentrated on adult patients of both genders with T2DM. Educational attainment beyond college level ranged from 5% to 69%, while two studies did not disclose participants' educational levels.[16,17] Selected publications were categorised into two groups: those reporting solely on the effect of the mobile applications on medication adherence and those reporting on both medication adherence and a clinical outcome. Details regarding the outcomes of selected studies are provided in Table 4.

Features of the Applications

Applications employed various strategies to enhance disease management and medication adherence. These tactics encompassed medication reminders, educational content dissemination, data tracking, and consultation with healthcare professionals. Four applications utilised medication reminders through notifications, aiding patients in remembering and adhering to their medication schedules.[17–20] Educational content or learning features were integrated into three applications to enhance patients' understanding of T2DM, its treatment, and lifestyle recommendations.[19–21]

One application incorporated blood glucose testing reminders for data collection to monitor clinical responses, issuing alerts if uploaded data deviated from predefined standards.[18] Five applications facilitated communication through two-way interaction between users and clinical support providers, fostering engagement and support.[17–20,22]

Adherence Measures

All studies analysed utilised subjective approaches to evaluate adherence, as detailed in Table 4. The table presents both statistically significant and insignificant findings, with insignificant outcomes indicated as 'ns'. However, variations or inconsistencies arise from the heterogeneity across the publications. Self-reported questionnaires were utilised to gauge adherence among the seven studies included: Voils Score (n = 1), Adherence Starts with Knowledge-12 (n = 1), the Medication Adherence Report Scale (n = 1), the Adherence to Refills and Medication Scale (n = 1), and the 6-item Morisky Medication Adherence Scale (n = 1) were the tools employed for self-reporting adherence in five studies, while the remaining two articles did not specify the questionnaire used. Notably, only one of the seven studies employed a mobile for conducting the questionnaire application.[21] In summary, four out of the seven selected studies demonstrated statistically significant improvements in medication adherence among T2DM patients, attributed to the intervention of a mobile application.[17,18,20,22]

Effects in Improving Health Outcomes

While studies did not directly assess patient health outcomes to gauge medication adherence, they instead analyse changes in clinical response as an alternative metric. To ensure comprehensive conclusions, the following findings spotlight studies that documented shifts in clinical outcomes, with a focus on the statistical significance of these changes. Six out of seven studies included measurements of clinical health outcomes which is haemoglobin A1c (HbA1c) levels. Among these, four studies exhibited statistically significant decreases in glucose levels, either within both control and intervention groups or during post-intervention assessments.[17,18–22] One study did not provide data on health outcomes.[19] Meanwhile, one other study reported a change in health outcome that was not statistically significant.[20]

Quality Assessment

The evaluation of the risk of bias in the included studies is showed in Tables 5 and 6. Among seven studies, five

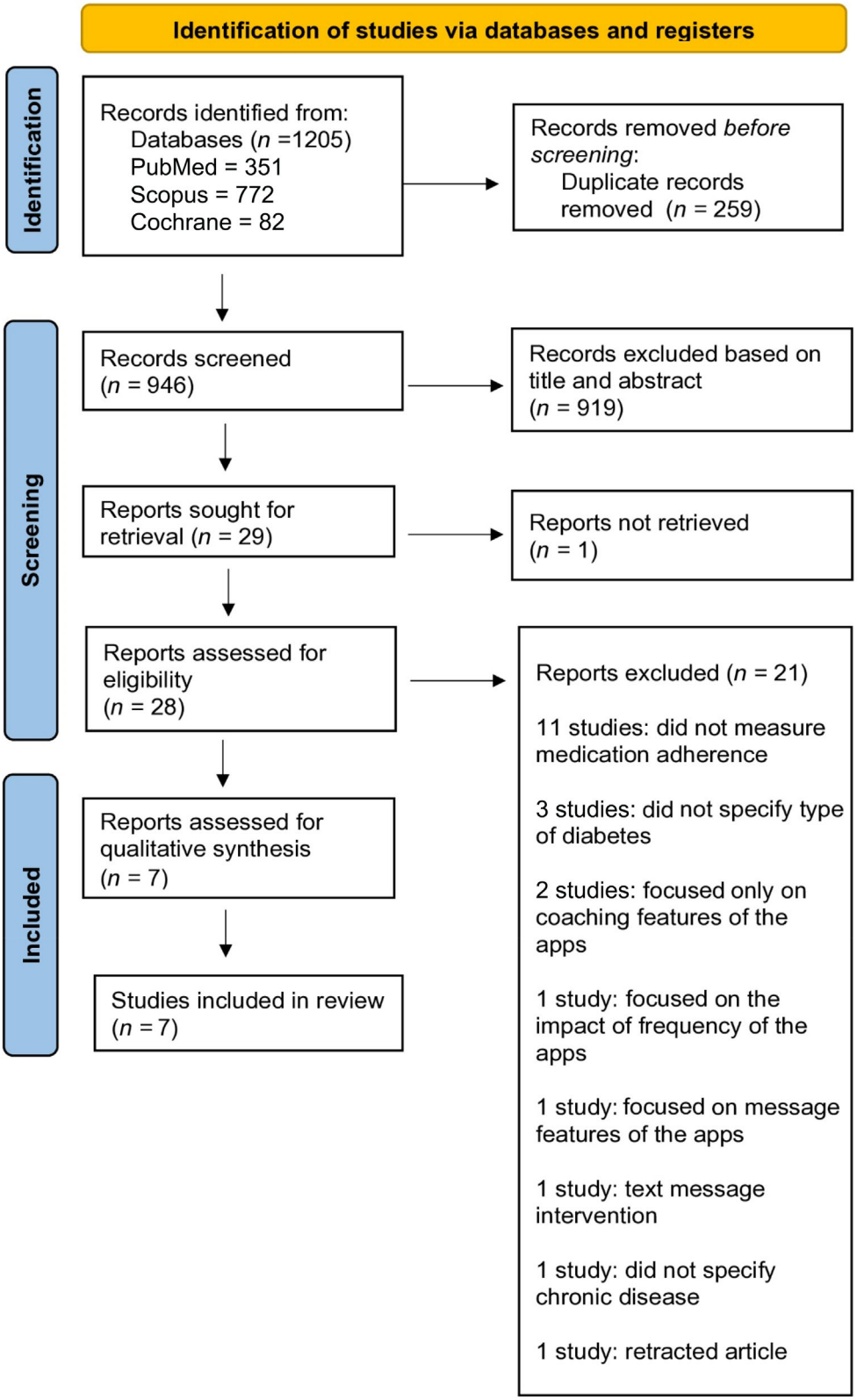

Figure 1 PRISMA flow chart.

Table 3 General characteristics of included studies and participants

Authors	Year	Country	Mobile app	Study design	Sample size	Mean age, years	Female (%)	Duration	Participants characteristics	Education level (%) ≥ college
Kleinman et al.[18]	2017	India	Gather Health	RCT	IG = 44 CG = 46	IG = 48.8 CG = 48.0	30.0	6 months	Patients diagnosed with T2DM for >6 months, A1c of 7.5%–12.5% at diabetes-focused clinics in India	26
Kjos el al.[19]	2019	USA	Medsimple	Prospective, observational, single-cohort study	51	52.3	54.9	6 months	Adult patients living in communities with T2DM in the USA who are taking a minimum of 2 prescribed medications	69
Huang et al.[20]	2019	Singapore	Medisafe	RCT	IG = 22 CG = 19	IG = 51.5 CG = 52.0	51.2	12 weeks	Patients diagnosed with T2DM, age ≥21 years old, on insulin or oral hypoglycaemic agents, and English speakers	59
Chao et al.[21]	2019	Taiwan	IPMF	Experimental design and RCT	IG = 49 CG = 48	63.1	39.0	2 years	Patients diagnosed with T2DM within the prior 3 months, HbA1c ≥5.4%, oral glucose tolerance test results >140 mg/dL	5
Yang et al.[17]	2020	Korea	Hicare Smart K	RCT	IG = 150 CG = 70	IG = 54.1 CG = 60.6	49.4	3 months	Outpatients attending primary care clinics diagnosed with T2DM and having HbA1c levels ranging from 7%–10% (53–86 mmol/mol)	ns
Batch et al.[16]	2021	USA	Time2Focus	Pilot study	IG = 100 CG = 101	57.3	49.8	12 weeks	Patients diagnosed with T2DM, HbA1c ≥8% and <12% in the past 3 months at primary care clinic in North Carolina	ns
Orozco-Beltrán et al.[22]	2022	Spain	DeMpower	Ambispective Study	IG = 11 CG = 6	IG = 63.3 CG = 64.4	34.0	52 weeks	Patients with HbA1c levels ranging from ≥7.5% to ≤9.5%, who were undergoing treatment with non-insulin antihyperglycaemic agents, and were being treated at healthcare facilities in Spain	26

A1c = haemoglobin A1c; CG = control group; HbA1c = haemoglobin A1c; IG = intervention group; IPMF = interactive personalised management framework; ns = not stated; RCT = randomised controlled trial; T2DM = type 2 diabetes mellitus; USA = United States of America.

Table 4 Outcomes of the studies using measures of adherence

Authors	CG	App functions	Relevant outcome	Adherence measure	Clinical outcome measure
Kleinman et al.[18]	Usual care	Medication reminders, data collection, and visualisation, blood glucose test reminders, behavioural assessment, collaborative care decision	Self-reported medication adherence	Mean adherence IG = 39.0% CG = 12.8% (p = 0.03)	Reduction in HbA1c levels IG = 1.5% CG = 0.8% (p = 0.03)
Kjos et al.[19]	Pre-intervention assessment	Behaviour change technology, action planning, prompts/cues, self-monitoring of behaviour, shaping knowledge, and medication reminders.	ARMS	Mean ± SD at 90 days 18.12 ± 3.84 Mean ± SD at 180 days 17.56 ± 3.51 p = 0.295()^{ns}	-
Huang et al.[20]	Usual care	Medication scheduling, reminder, tracking, data sharing, and medication adherence assessments	ASK-12	ASK-12 Mean ± SD IG = 28.6 ± 5.2 CG = 25.5 ± 4.4 (p = 0.01)	Mean ± SD in HbA1c IG = 9.0 (1.6) CG = 9.4 ± 2.4 (p = 0.57)^{NS}
Chao et al.[21]	Usual care	Integrates and display patients' information, education that integrates with patient collected information, behavioural changes assessment	Mobile questionnaire	Mean ± SD Pre-intervention = 4.6 ± 0.7 Post-intervention = 4.4 ± 1.0 (p = 0.42)^{ns}	Change in HbA1c (p = 0.003)
Yang et al.[17]	Usual care	Data collection, transmission of data to server, reminders	MMAS-6	Mean change IG = 0.52 CG = 0.45 (p = 0.01)	Mean change in HbA1c IG = −0.63 CG = −0.28 (p = 0.003)
Batch et al.[16]	Usual care	Patient education through interactive learning experience	Voils score	Mean change IG = −0.18 (p = 0.11)^{ns}	Mean change in HbA1c IG = −0.32 CG = −0.39 (p = 0.78)^{ns}
Orozco-Beltrán et al.[22]	Usual care	Data from the commercially available devices were wirelessly received by the app, consultation	MARS-5	Mean adherence IG = 24.3 CG = 23.0 (p = 0.05)	Mean reduction in HbA1c IG = −0.81 (0.89) CG = −0.15 (1.03) (p = 0.03)

ARMS = Adherence to Refills and Medication Scale; ASK-12 = Adherence Starts with Knowledge-12; CG = control group; HbA1c = haemoglobin A1c; IG = intervention group; MARS-5 = Medication Adherence Report Scale; MMAS-6 = 6-items Morisky Medication Adherence; ns = not significant; SD = standard deviation.

were classified as high quality, one was considered moderate quality, and one was categorised as low quality.

A primary concern regarding bias was associated with inadequate reporting of the randomisation process.[17,20] This deficiency in reporting raises doubts about the credibility of the randomisation process, potentially impacting the selection of participants into different treatment groups. Another potential bias was that groups deemed comparable at baseline were unclear.[18,21] This lack of comparability introduces uncertainty about the differences between the interventional and control groups, compromising the accuracy of assessing the intervention's impact and the validity of study findings.

Furthermore, two studies had unclear blinding of the outcome assessor.[21,22] This lack of clarity in blinding introduces potential bias by influencing the impartial assessment of outcomes. Another source of bias was incomplete outcome data, particularly noted in one study, where a high risk of bias arose due to a significant number of participants withdrawing from the study.[22] Incomplete outcome data can lead to attrition

Table 5 Summary of risk of bias for randomised controlled trials

Risk of bias						
Study	D1	D2	D3	D4	D5	Overall
Chao et al.[21]	● Low	○ Unclear	● Low	○ Unclear	● Low	○ Unclear
Huang et al.[20]	○ Unclear	● Low	● Low	● Low	● Low	● Low
Kleinman et al.[18]	● Low	○ Unclear	● Low	● Low	● Low	● Low
Orozco-Beltrán et al.[22]	● Low	● Low	● High	○ Unclear	● High	● High
Yang et al.[17]	○ Unclear	● Low	● Low	● Low	● Low	● Low

D1 = bias due to randomisation process; D2 = bias due to incomparable groups at baseline; D3 = bias due to incomplete outcome data; D4 = bias due to lack of binding of outcome assessors; D5 = bias due to nonadherence of participants to the assigned intervention.

Table 6 Summary of risk of bias for non-randomised studies

Risk of bias						
Study	D1	D2	D3	D4	D5	Overall
Batch et al.[16]	● Low	● Low	○ Unclear	○ Unclear	● Low	● Low
Kjos et al.[19]	● Low	● Low	● Low	● High	● Low	● Low

D1 = bias due to lack of representativeness in the population; D2 = bias due to inappropriate outcome and intervention measurements; D3 = bias due to incomplete outcome data; D4 = bias due to confounding factors; D5 = bias due to deviation from intended intervention.

bias, impacting the reliability of intervention effect estimates.

DISCUSSION

The researchers conducted a systematic review of published studies to assess the effectiveness of mobile device applications in improving medication adherence among patients with T2DM. Although all seven studies reported positive outcomes from their mobile application interventions in improving medication adherence in compared to control group, three studies did not demonstrate statistically significant effects in enhancing medication adherence. Meanwhile, only four studies showed statistically significant results in reducing HbA1c levels.

The features of these applications collectively contribute to an enhanced patient experience and improved health outcomes. The combination of medication reminders ensures consistent adherence, reducing the likelihood of missed doses and promoting treatment compliance. Educational content dissemination empowers patients with knowledge about their condition, treatment options, and necessary lifestyle modifications, fostering a sense of autonomy and informed decision-making. Data tracking features enable users to actively monitor their clinical responses, facilitating a more personalised and data-driven approach to disease management. Additionally, the incorporation of two-way communication channels with healthcare professionals establishes a supportive environment, allowing for real-time interaction, prompt clarification of doubts, and tailored interventions based on individual patient needs.

The holistic integration of these features reflects a patient-centric approach, where technology not only aids in administering medication but actively engages and empowers individuals, leading to a more proactive and informed involvement in their health management. As technological advancements continue, the ongoing refinement and expansion of these features hold the promise of further elevating the impact of mobile applications on patient outcomes and overall healthcare efficacy.[23]

Self-reported questionnaires are one of the many subjective methods to assess adherence. Self-report questionnaires represent the simplest and most straightforward method of gathering information, offering an inexpensive and convenient approach for assessing adherence in both naturalistic studies and clinical practice.[24] These measures are defined by asking respondents to characterise their medication adherence behaviour.[25] Major benefits comprise affordability, non-intrusiveness, minimal patient imposition, simplicity in application, and adaptability in both timing and method of delivery.[26]

The potential drawbacks associated with self-report questionnaires should be considered, including the possibility of respondents providing inaccurate answers. This could stem from factors such as social desirability bias, where participants may feel compelled to present themselves in a favourable light,[27] therefore researchers should remain vigilant about the limitations inherent in self-reported data and consider employing additional validation measures where possible.[28] Moreover, questionnaires can be difficult for patients with lower literacy levels.[29]

This review identified a notable heterogeneity in the types of self-reported adherence measures employed across the included studies. While this variability introduces some complexity in direct comparisons, it also reflects the adaptability of mobile application interventions across diverse research contexts and populations. The use of various validated tools demonstrates that improvements in medication adherence were observable across multiple assessment frameworks. Although differences in questionnaire structure, scoring methods, and psychometric properties may contribute to some variation in reported outcomes, the overall trend across studies consistently supports the positive impact of mobile applications. There is not a one-size-fits-all answer to ranking the best questionnaire for assessing medication adherence, as it depends on various factors such as the specific population being studied, the context of the research or clinical setting, and the purpose of the assessment.

Strength and Limitations

This review, centred on the utilisation of mobile applications by T2DM patients and their influence on adherence, showcases a thorough approach by encompassing studies irrespective of their methodological design and the quality of the applications employed. While this inclusivity offers a comprehensive perspective, it simultaneously presents both strengths and limitations. On one hand, it provides a broad overview of the topic, but on the other, it introduces challenges associated with heterogeneity. The incorporation of both randomised controlled trials (RCTs) and non-RCTs is significant. Although study quality did not lead to exclusion, all selected studies were evaluated as having moderate to high quality. This indicates that the review included the most dependable evidence accessible regarding the subject matter. The methodological and clinical diversity among the studies emerged as a significant limiting factor, making it challenging to draw uniform conclusions. Additionally, the restriction to English-language papers may introduce a language bias, potentially excluding valuable insights from non-English literature.

Furthermore, the exclusion of individuals with type 1 diabetes, pre-diabetes, or gestational diabetes mellitus represents a specific scope, limiting the generalisability of the findings to a broader diabetic population. The reliance on self-reporting for measuring adherence introduces the potential for reporter bias, raising questions about the accuracy and reliability of adherence data. The variability in applications features and their complexities further adds to the heterogeneity, potentially influencing the overall efficacy of the applications studied.

It is crucial to recognise the existence of confounding variables that were not systematically examined in this review, including age, gender, cultural background, educational attainment, and socioeconomic status. These variables can profoundly influence patient adherence and should thus be considered in future research to offer a more nuanced comprehension of the associations between mobile applications utilisation, adherence, and patient demographics.

Conclusion

This systematic review investigated the impact of mobile applications on medication adherence in patients with T2DM. All seven studies noted favourable results from their mobile application interventions in enhancing medication adherence compared to control groups. Nonetheless, only four studies revealed statistically significant effects. Moreover, just four studies exhibited statistically significant outcomes in lowering HbA1c levels. However, definitive conclusions on the effectiveness of applications and their impact on medication adherence and clinical outcomes were challenging due to the overall low quality of available evidence and significant heterogeneity in study design, application features, and outcome measures. The evidence primarily stemmed from feasibility trials with generally low bias risk. Further advancements are warranted, and future investigations should concentrate on establishing standardised protocols for evaluating mobile application-based interventions targeting medication adherence. This approach seeks not only to pinpoint optimal applications features, but also to enhance user-friendliness and integrate patient-centric strategies to promote sustained adherence and improve health outcomes.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest.

AUTHORSHIP STATEMENT

Nur Adlina Ruslan: Methodology; Formal analysis; Conceptualisation; Investigation; Writing – original draft. **Nur Hannan Najihah Mohamad Tawpik**: Conceptualisation; Investigation; Writing – original draft; Methodology. **Syahrir Zaini**: Conceptualisation; Supervision. **Hussam Abdeljabar Ahmad Mizher**: Conceptualisation; Investigation; Writing – original draft; Writing – review & editing; Validation; Methodology; Formal analysis; Project administration; Supervision.

ETHICS STATEMENT

Ethics approval was not required for this systematic review as it utilised published data and did not include human participants.

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OPEN ACCESS STATEMENT

None.

DATA AVAILABILITY STATEMENT

The data included in this systematic review were obtained from publicly available datasets and published studies. Further details can be found in the references cited in the manuscript.

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