

Factors influencing patients' adoption and use of mobile health applications for diabetes self-management: a systematic review



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Abstract Mobile health (mHealth) apps can facilitate diabetes self-management (DSM) and assist in reducing the risk of complications, enhancing diabetes control and improving patient outcomes. The objectives of this systematic review were to (1) determine the adoption level of DSM apps among diabetes patients, (2) identify the factors associated with the adoption and use of DSM apps, and (3) explore patients' perspectives of DSM apps and the predominant preferred features. A comprehensive literature search was performed in four electronic databases: PubMed, Scopus, PsychNet, and IEEE Xplore digital library using the PRISMA guidelines. Relevant data and information were collected from studies published between 2016 and 2023, fulfilling the inclusion criteria ($n = 26$), and thematic analysis was performed. The adoption level of mHealth apps for DSM among diabetic patients ranged from 7.0% to 47.0%, and diverse factors relating to patients' demographics, preferences and experiences were identified. Overall, older, male and less educated patients were less likely to adopt DSM apps, while the intention to use these apps was influenced by patients' perceived benefits, recommendations by patients and healthcare professionals, and ease of use. Given that most of the reviewed studies were conducted in developed countries, the present patients' adoption level of mHealth apps for DSM is relatively low, thereby highlighting the need for improvement. The factors identified in this study may be considered when attempting to encourage patients to use these apps. More research is needed to elucidate how mobile health apps can be effectively integrated into diabetes care and management pathways.

Keywords: mobile health, diabetes, self-care management, diabetic patients, adoption

1. Introduction

The prevalence of diabetes continues to depict an increasing trend globally, affecting 1 in 11 people (International Diabetes Federation, 2019). Both microvascular and macrovascular complications may arise from persistent hyperglycemia, thus increasing the risk of fatality, especially among young individuals (Wou et al., 2019). The management of these complications places a significant burden on healthcare facilities and resources (Nichols et al., 2019). Persistent hyperglycemia and insulin resistance are common in type 2 diabetes, which is the most prevalent form of diabetes worldwide. The increasing prevalence of this condition and the fact that most patients are managed in primary healthcare centers have heightened the demands for healthcare professionals' input and clinical appointments. As a result, discussions on diabetes management and optimized treatment cannot be effective between clinicians and patients (Alaslwi et al., 2022). Nevertheless, diabetes self-management has been demonstrated to enhance glycemic control and decrease the risk of diabetes-related complications (Lee et al., 2019).

Self-management is critical in diabetes management (Funnel, 2000), which is similar to the term "self-care". While self-care encompasses behaviors and activities performed to manage acute diseases or injuries and focus on treatment (Royal College of Nursing, 2020), self-management refers to the strategies employed by patients in coping with practical and emotional issues experienced while suffering from a chronic disease or illness. DSM in type 2 diabetes patients entails maintaining a healthy diet and lifestyle, adhering to prescribed medication, managing symptoms of hyperglycemia or hypoglycemia and frequent monitoring of blood glucose levels (Shrivastava et al., 2013). Moreover, it is challenging for diabetic patients to cope with the increased risk of death and disability (Lin et al., 2020). Hence, to influence patients' behavior and improve their engagement with diabetes care, self-management and support are crucial, particularly during diagnosis (Powers et al., 2017). DSM education and support from healthcare professionals are usually provided upon initial diagnosis, which is then accompanied by support from community resources and other practitioners (Powers et al., 2017).

Given the burden on healthcare resources and limitations associated with face-to-face consultations and education courses, the need for autonomous DSM is widely supported by healthcare professionals (Lee et al., 2019). Digital technology



and mobile health apps have been demonstrated to motivate autonomy and self-care management and enhance diabetes management outcomes (Greenwood et al., 2017). Wireless technologies such as continuous glucose monitoring devices, blood glucose meters and smart insulin pumps and pens are widely acceptable to augment treatment and lifestyle interventions (Fleming et al., 2020). Nevertheless, mobile health apps have been the frontline innovations for diabetes self-management, focusing on different interventions, such as physical activity, nutrition, glucose monitoring, artificial pancreas systems, and insulin titration and delivery (Fleming et al., 2020).

Several studies have depicted the effectiveness of mobile apps in reducing barriers to self-management activities, either by educating diabetes patients, facilitating trend viewing and data logging, and sharing data with healthcare professionals (Basulico et al., 2016). In addition, mobile apps are useful components for effective lifestyle modification (Beck et al., 2017), as reflected in the improvement in patient-healthcare professional communication, a significant decrease in hemoglobin A1c levels among type 2 diabetes patients (Wu et al., 2017), and facilitation of remote disease monitoring (Fatehi et al., 2017).

Despite these encouraging findings, the adoption and use of diabetes management apps are influenced by patients' experiences and demographics, app functions and features, and recommendations by other patients and healthcare professionals (Zhang et al., 2019). Diverse theoretical models have been employed to investigate diabetes self-management app adoption, but only a few studies have assessed the factors influencing healthcare professionals' recommendation of such apps to their patients and incorporating the findings into clinical practice (Byanbasuren et al., 2019). Meanwhile, a few reviews have attempted to explore the factors influencing the adoption of DSM mHealth apps among patients, but most of the reviewed studies were empirical and thematic analyses of healthcare professionals or patients' perspectives were not explored. Therefore, this article presents a comprehensive systematic review of the predictors of diabetes self-management apps among patients and healthcare professionals. Apart from summarizing the empirical findings from the relevant studies, the results are supported with verbatim comments and themes synthesized from qualitative studies, thereby providing the opportunity for data triangulation.

2. Materials and Methods

The procedures followed in this review aligned with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement, an instrument designed to prepare a robust, transparent and accurate review (Page et al., 2021). We decided to apply the PRISMA statement given its suitability to achieve our research objectives as it provides a clear definition of research questions, exclusion and inclusion criteria, and selecting a specific timeframe for the identification of relevant and accessible articles (Shamseer et al., 2015).

2.1. Development of research question

The research questions in this review were formulated using PICO, a research question development tool (RQDT). PICO is an acronym in which P = population, I = intervention, C = comparison, and O = outcome, and the three main concepts are Population or Problem, Interest and Context. Considering the population of interest as diabetes patients and healthcare professionals, mHealth apps as the intervention, healthy patients as the comparison group, and adoption and associated factors and perspectives as the outcomes, the following research questions were synthesized:

1. What is the adoption level of DSM apps among diabetes patients and healthcare professionals?
2. What are the predictors/determinants or factors associated with the adoption and use of DSM apps among diabetes patients?
3. What are the perspectives of diabetes patients and healthcare professionals regarding DSM apps and the predominant features looked out for?

2.2 Literature search process and eligibility criteria

Relevant articles published between 2016 and 2023 were considered during the literature search in 4 databases: PubMed, Scopus, PsychNet, and IEEE Xplore digital library. In line with the core elements and objectives of this systematic review, the search items were broadly categorized into five components: adoption, mobile apps, diabetes patients, healthcare professionals, and perspectives. Alternatively, some other keywords were considered under each component with other wordings, which were depicted by the Boolean operator "OR". Each component was combined with other subkeywords using the separator "AND". The following reflects the database evaluated for the words beginning with specific denoted by an asterisk:

1) To retrieve articles involving diabetes patients. Other words were permitted by the operator "OR" for the main component "diabetes patients".

a. ("type 2 diabetes patients" OR "T2DM")

AND:

2) To retrieve articles with adoption, associated factors and perspectives as the main outcomes. The Boolean operator “OR” was used to permit alternative wordings, including

- a. (adoption* OR (uptake, use, acceptance, implement *),
- b. (perspectives* OR (views, attitudes, perception*))
- c. (Associated factors* OR (predictors, determinants*)).

3) To retrieve all possibly relevant studies on mobile health apps.

- a. (mobile health apps* OR (mHealth, apps, digital health intervention, smartphones*)).

The references of the selected articles were checked manually for relevant studies that fulfilled the inclusion criteria. The search strategy employed for PubMed was adopted for the literature search in other databases. The literature search and study selection criteria are presented in Figure 1.

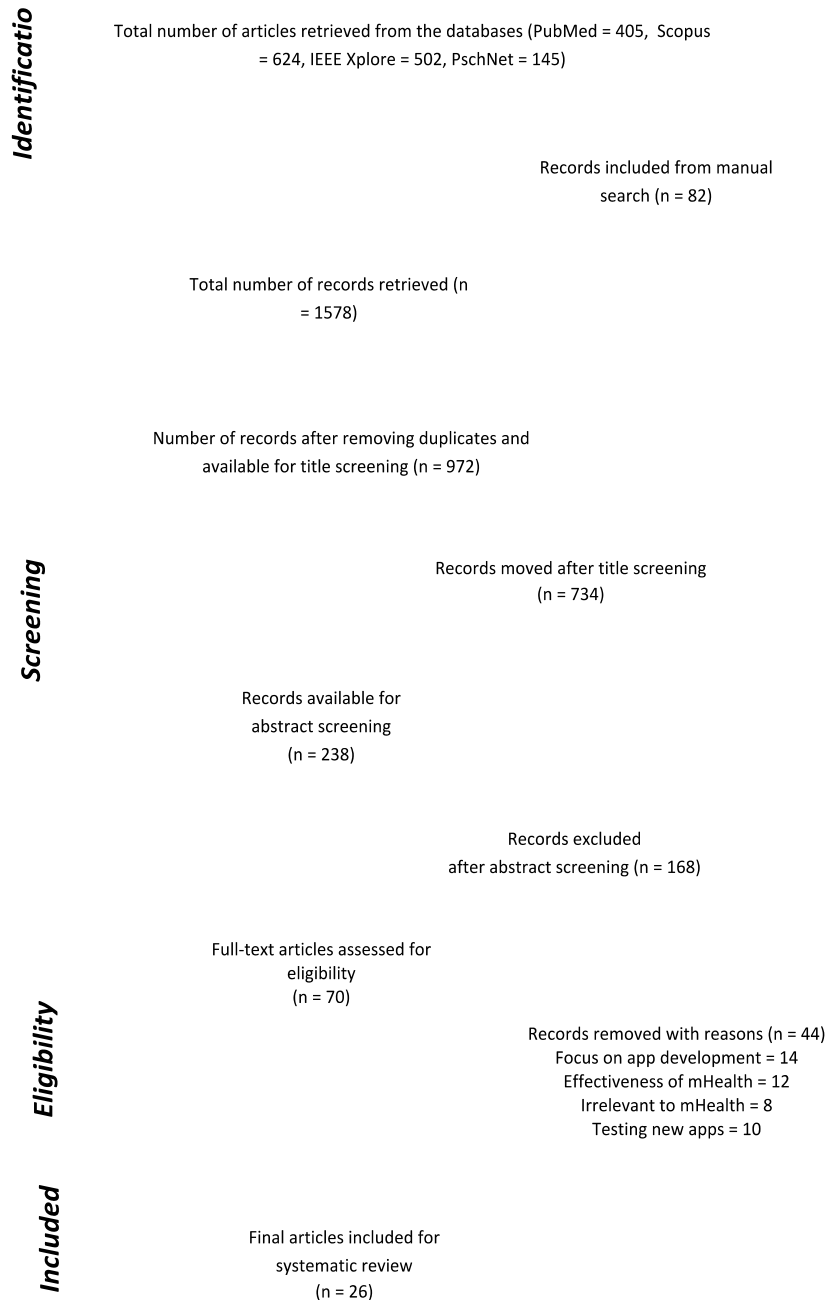


Figure 1 Study selection flowchart using the PRISMA guidelines.

2.3. Study selection



Qualitative and quantitative research written in English and reporting the adoption or use of mHealth apps for DSM among patients and healthcare professionals were retrieved from the primary literature research. Consequently, only original research articles, short communications, and research presented at conferences were subjected to further review. Meanwhile, book chapters, review articles, and inaccessible full-text articles were excluded. The retrieved articles were assessed for duplicates, and all identified duplicates were removed. Thereafter, the titles and abstracts of the studies were independently examined by two reviewers according to the eligibility criteria. Any disagreement regarding the eligibility of a specific article was addressed by consulting a third investigator. Finally, the full texts of the selected articles fulfilling the eligibility criteria were read, and the findings were summarized.

2.4. Data extraction, synthesis and analysis

Two independent authors carried out the data extraction from the selected studies. The extracted data comprised the references, study design and location, type of DSM mobile apps utilized, and the main findings. The information to be extracted was specified by the corresponding author of this review, who was also responsible for the final decision on articles with missing data. For the qualitative studies, data synthesis was performed using the methods described by Thomas and Harden (2008), which entails three main steps: line-by-line coding, formation of descriptive themes by organizing the free codes, and the synthesis of analytical themes. Data relating to determinants, predictors, or factors associated with patients' or healthcare professionals' use or adoption of mobile DSM apps were coded by the first author. Similar codes were highlighted and categorized as descriptive themes for consistent data patterns. Thereafter, analytical themes were developed by probing the descriptive themes.

2.5. Risk of bias assessment

Since this review included studies that used either qualitative or quantitative research methods, different instruments were used to assess the risk of bias in the included studies. For the quantitative studies, two reviewers employed the Newcastle–Ottawa (NOS) scale developed by Wells et al. (2014) to categorize each study based on three broad criteria: selection of study groups, similarity or comparability between the groups, and outcome measurement, which were used to allocate a score ranging from 1 to 9. Studies with scores < 5, 5–7, and > 7 were considered of low, moderate and high quality, respectively.

The framework described by Spencer et al. (2003) is underpinned by four key principles: contribution to the existing knowledge pool, defensibility of the research method, rigorous conduct, and credibility of the findings and conclusions. These principles were then applied to formulate 18 questions covering the research findings, methodology, sample, data collection and analysis, reporting of results, reflexivity, neutrality, ethics and audibility.

3. Results

3.1. Descriptive Analyses

3.1.1. Characteristics of the Included Studies and Participants

As illustrated in Figure 1, a total of 26 articles were included in the final analysis, comprising mostly qualitative studies ($n = 12$), quantitative studies ($n = 11$), and mixed methods ($n = 3$). Six of the retrieved articles were published in 2019; 4 studies each were published in 2016, 2017, 2021, and 2022, while only one article was published in 2023. Approximately two-thirds (62%) of the studies were conducted in developed countries ($n = 16$) compared to those reported in developing countries ($n = 10$). All the studies collected primary data.

T2DM patients were the predominant patients in the reviewed studies (60%), while 20% of the studies included both T2DM and type 1 diabetes mellitus, and less than 10% were nonspecific diabetes patients. In terms of sample size, most of the studies involved fewer than 150 participants (70%) compared to 20% in which participants ranged from 150 to 500, and 10% involved more than 500 participants. All the participants in the reviewed studies were > 18 years old. Diverse mHealth apps and interventions were investigated in the reviewed studies. Table 1 presents the pertinent data extracted from the studies, including the study designs, mHealth apps used, main findings, and especially the associated factors and determinants of mHealth adoption for DSM.

3.2. Risk of bias assessment findings

As shown in Table 2, 14 of the quantitative and mixed method studies received NOS scores of 6–7, indicating moderate quality, while the remaining 3 articles obtained NOS scores > 7, indicating low risk of bias and high methodological quality. Overall, none of the included studies recorded a high risk of bias. In contrast, none of the qualitative studies obtained a score > 7, as most of the studies ($n = 8$) recorded scores of 5 and 6, indicating a moderate risk of bias (Table 3).

Table 1 Descriptive analyses of the studies included in this systematic review and the main findings.

Authors	Aim/objectives	Study design	Targets/participants	Findings
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			and location		
1	Abd-alrazaq et al., 2021	Exploring patients' and educators' experiences about their communication pre and postimplementation of diabetes management app.	Qualitative study	9 patients and 5 nurses educators in Qatar	The mobile health app was a more efficient and convenient technique for patients to communicate with healthcare workers, nevertheless, several constraints were raised and suggestions for improvement. Nevertheless, multiple shortcomings and several suggestions for improvements were noted.
2	Mehbodniya et al., 2021	The adoption and use of smartphones for self-management of diabetes	Cross-sectional (quantitative)	200 diabetic patients (especially type 2) in India	The present and future use of smartphone apps for diabetes self-management was higher among younger participants. Most participants (>70%) employed apps for nutritional planning, monitoring glucose control, and scheduling diabetes appointments. 20.5% of participants reported healthcare professionals' recommendations to use mobile app
3	Yu et al., 2021	Acceptability to adopt mHealth apps for T2DM self-management among Chinese and Hispanic immigrants	Mixed methods design.	Chinese and Hispanic immigrants (n = 118).	The factors influencing participants' intention to use the apps were performance expectancy and effort expectancy. While the barrier to usage was poor eyesight, the provision of technical support by family members was an important facilitator.
4	Yu et al., 2022	Explores the factors associated with diabetes self-management among patients with diabetes	Qualitative (Focus-group discussion)	Healthcare professionals and patients (n = 56) were purposively selected in Singapore.	Poor commitment to lifestyle modification, low medication adherence, insufficient interaction between patients and HCPs, and patient resistance to insulin initiation were the barriers to self-management. Meanwhile, facilitators of self-management were social support from family and community, patients' perceived susceptibility to complications, multidisciplinary team care and patient's knowledge of the advantages of self-care
5	Jain et al., 2019	Factors influencing the adoption of diabetes self-management apps among adult diabetic patients and healthcare workers	Qualitative		The use of mHealth apps was influenced by patients' personal qualities and healthcare workers' concerns. Features such as easy usage, access and application were preferred by patients. While patients' ambitions or drive were motivating, personal qualities such as illiteracy, language barrier, and low technological competence were barriers to app usage. HCPs opined that despite the benefits of such interventions, there are issues with integrating them into clinical practice and workflows.
6	Bonet Olivencia et al., 2021	Investigates the design requirements by key stakeholders for a mHealth app among medically underserved diabetic patients	Quantitative survey	A total of 97 diabetic patients and 11 healthcare professionals in South Texas, USA	Rather than using textual forms, patients conveyed the need for accessible educational content to guide them on regulating diet, blood sugar, and physical activity via multimedia. According to healthcare providers, the top-ranked app features were educational content, glucose monitoring, and the graphical presentation of diabetes data. These findings suggest that specific design requirements for the underserved can improve the adoption, usability, and sustainability of such interventions. Designers should consider health literacy and numeracy, linguistic barriers, data visualization, data entry complexity, and information exchange capabilities.
7	Jacobs-Basadien et al., 2022	Explored the impact of culture on mHealth acceptance among diabetic patients	Qualitative study	20 participants in South Africa	Culture had a significant impact on the participants' adoption of m-health applications. Cultural dimensions relating to masculinity-femininity had a negative effect while positive influence was elicited by indulgence. Meanwhile, uncertainty avoidance reflected both negative and positive influences on m-health app adoption.
8	Prihatin Putri et al. 2022	To optimize the treatment of T2DM by initiating an Android-based mHealth app technology for patients, healthcare providers and family members	Study protocol (mixed-method)	Indonesia	The first phase is an in-depth interview and FGD among patients and healthcare workers, while the second phase entails the development of an Android-based application based on the results gleaned from the initial phase. results. Users' feedback will be collected in the third phase to determine the effectiveness of the apps based on improved self-management and glycemic control.
9	Su et al., 2020	To elucidate the association between personality traits and the use of mHealth apps (DiaSocial) for the management of diabetic patients	Quantitative study	98 diabetic patients in China	The prevalence of mHealth app use was 47%. Factors associated with higher use of these apps were younger patients ($P = 0.02$, OR= 0.91, 95% CI 0.85-0.98), extraversion ($P = 0.04$, OR 0.71, 95% CI 0.51-0.98), and openness to experience ($P = 0.03$, OR 1.73, 95% CI 1.07-2.80). Gender, higher educational qualification, and baseline HbA _{1c} level were not associated with the adoption of the app.
10	Jeddi et al., 2020	T2DM Patients' usage of smartphone and their intention to use them for self-management.	Cross-sectional study	176 patients with T2DM in Iran	Younger participants were more likely to use the apps, and approximately half of the patients posited that using the apps can be interesting (53.8%) and useful (50.2%) for diabetes management. Nearly half of the participants demonstrated the

intention to use the apps in future (48.3%).

11	Brew-Sam et al., 2020	The effect of family and healthcare professional support on the use of diabetes self-management mobile app	Mixed method: exploratory semistructured face-to-face interviews and an online survey	Adult type 1 and type 2 diabetes patients in Singapore. (N = 21 and 65 for studies one and two, respectively)	Healthcare professionals' shared decisions and supportive communication were influenced by their medical specialities. Supervision by diabetes specialists increased the odds of app use compared to supervision by general practitioners. Furthermore, the likelihood of shared decision-making and better physician-patient communication was influenced by specialist care. Meanwhile, the likelihood of app use increased when less informal support (family and friend support) was provided.
12	Jeffery et al., 2019	To explore the barriers, experiences, and facilitators to app usage among T2DM patients and suggestions to enhance the usage of diabetes mHealth apps.	Qualitative study	A total of 16 apps and 14 nonapp users in Australia participated in the semistructured phone- interviews	Patients were more satisfied when the apps were recommended by health professionals but only a few patients reported having such professions in their app usage. Motivating factors for app use were the visual representation of trends, convenience, and intuitive navigation, whereas barriers were users' low awareness and lack of knowledge, technological and health literacy, and perceptions of disease severity. The main recommendations for future mHealth app design focused on educational features, monitoring and tracking features such as nutritional features, monitoring of blood glucose levels and trends of comorbidities).
13	Huang et al., 2023	Comparisons of the glycemic control levels between eHealth app users and nonusers.	A quantitative study involving T2DM patients	Participants comprised 76,356 nonusers and 31,723 users of the eHealth App in Hong Kong	More optimal HbA1c levels were observed among the users of the eHealth management module across all subgroups, and younger females demonstrated the strongest effects (OR = 1.66, 95% CI = 1.27–2.17)
14	Humble et al., 2016	Patients' use of and interest in mHealth for diabetes self-care in vulnerable populations.	Cross-sectional and quantitative	75 patients visiting a hospital in the USA	Factors that increased the interest and usage of mHealth applications for diabetes self-management were smartphone users and younger patients.
15	Conway et al. 2017	This study gauges diabetes app user opinion to inform development work.	Quantitative	400 patients in the UK stratified by diabetes type and age	The adoption level of mHealth for diabetes self-care use was low (7%) despite 71% of the participants expressing a preference toward mHealth.
16	Trawley et al., 2017	To determine the relationships between clinical, demographic, and psychosocial variables and diabetes-specific app usage.	Quantitative	A national cross-sectional survey among 1589 participants in Australia	Patients with shorter diabetes duration, engaging in frequent monitoring of blood glucose levels, and lower self-reported HbA1c were more likely to use the diabetes-specific app. Glucose monitoring (62%) was the main reason for using the app among adult patients with type 1 DM. Irrespective of diabetes type, the belief that using apps will not assist in diabetes self-management was the main reason for not using the app.
17	Rafiullah and David, 2019	To investigate patterns of usage regarding different smartphone health applications among diabetic patients	Quantitative	Saudi Arabia	The adoption level of mHealth apps was 36.62%. Patients preferred to use such apps for blood glucose measurement follow-up, body weight, exercise, and calorie intake monitoring. More than one-third of participants posited that training was necessary.
18	Ernsting et al., 2019	To determine the factors influencing mHealth use among individuals with CVD or diabetes	Quantitative study population-based	A total of 1500 individuals in Germany comprised 3 subgroups: those with CVD (n = 1325), diabetes (n = 681), and those with both conditions (n = 524).	The adoption level and use of mHealth apps was approximately 25%, and the most prominent target behaviors were weight loss and physical activity. Overall, users were younger, females, more educated with higher eHealth literacy, and engaged in one or more physical activities.
19	Mathiesen et al., 2017	To evaluate the impact of digital intervention in enhancing diabetes management in vulnerable T2DM patients	A qualitative design using semistructured in-depth interviews	12 patients visiting a hospital in Denmark	Thematic analyses yielded 4 main themes namely, 1) "Dealing with diabetes distress" which was characterized by psychological avoidance mechanisms; 2) "Experiencing digital alienation" which entails the loss of freedom in response to the invasion of privacy by the new technology, 3) "Suffering informational confusion" which relates to addressing inconsistent information, and 4) "Missing the human touch" favoring face-to-face or human interaction over digital contact.
20	Boyle et al., 2017	To elucidate the usage of the diabetes self-management mHealth	Cross-sectional survey	A total of 539 people in New Zealand	The adoption rate of the mhealth app was 19.6% (37/189), and the use was higher among younger patients and those with type 1 DM compared to older and other types of diabetes. The

		app among individuals and the app features desired.			features desired by users were a glucose diary (87%), and an insulin calculator (46%).
21	Peng et al., 2016	To elucidate the perceived benefits, barriers, and facilitators of the usage of mobile apps among rural adults with T2D	Qualitative study (focus group discussion)	18 participants with T2D in the United States	Thematic analyses yielded four themes: perceived benefits of desired features of diabetes self-management, perceived barriers to use or continuous use, information sharing with family, friends, and health professionals, and facilitators to motivate use
22	Pludwinski et al., 2016	Explored T2DM patients' experiences with the use of smartphone and self-monitoring software	Qualitative study (focus group discussion)	11 participants in Canada	Four main themes were derived from the thematic analysis, namely, 'smartphone and software', which entails the use of smartphone relative to health behavior change, 'health coach' which describes how the relationships between clients and health coaches were assisted by using smartphones, 'overall experience' describes participants' perceptions of the entire intervention; and 'frustrations in managing chronic conditions' elucidates the barriers and complexities of managing T2DM.
23	Zhang et al., 2019	Investigated the use, perspectives, attitudes and needs of diabetes patients regarding the self-care management app	Quantitative	1276 individuals from 30 provincial regions in China	The participants' awareness and adoption levels were 29.9% and 15.44%, respectively. The associated factors were diabetes type, and patients' age, educational level, family or household income, and location. Patients discontinued using the app due to limited time (25.3%), complicated operations (25.2%), ineffectiveness for glycemic control (24.3%), and high cost (19.3%).
24	Brandt et al., 2019	Explored patients' perspectives of a smartphone delivered intervention for self-management of diabetes-related complications	Qualitative study: In-depth Interviews	A total of 6 nurses and 29 patients with diabetes or hypertension or both in Peru.	Thematic analyses yielded six main domains: perceived usability, perceived health benefit, user satisfaction, adherence, nurse support, and suggestions for improvement. The issues raised include challenges in interacting with the app elements, such as Android notifications, short message service, and pop-up messages.
25	Kelly et al., 2018	To elucidate the effect of using mobile technologies to support T2DM management	Qualitative study: In-depth Interviews	11 patients in the UK	Thematic analyses yielded 7 themes, which focused on the vital aspects of employing technology to support self-management: information, reaching and sustaining goals, understanding individual health and personal data, minimizing disruption to daily life, communicating with healthcare professionals, reassurance, and coordinated care.
26	Torbjornsen et al., 2019	To elucidate users' acceptability of a mobile app for DSM	Qualitative study: In-depth Interviews	T2DM patients who had used the digital diabetes diary app for 1 year in Norway	Diverse views were observed regarding users' acceptability. Vital to the acceptability was that a routine use might provide an overview of diabetes registration and new insights into self-management. Participants posited that it is necessary to receive support from healthcare professionals with diabetes knowledge.

Table 2 Summary of assessment for quality appraisal and risk of bias in the 16 quantitative or mixed-method studies included in the systematic review according to the Newcastle–Ottawa Scale (NOS).

S/N	Authors	Selection			Demonstration that the result of interest was not present at the beginning of the study	Comparability		Outcome		Total score
		Adequate representative of the exposed group	Adequate selection of nonexposed group	Confidence in the standardization of exposition		Adjustment for confounders	Adjustment for measurement of the outcome	Sufficiency of follow-up for event development	Losses from follow-up	
1	Mehbodniya et al., 2021	+	+	+	+	+	+	+	+	8
2	Yu et al., 2021	+	+	+	+			+	+	6
3	Bonet Olivencia et al., 2021			+	+	+	+	+	+	6
4	Prihatin Putri et al., 2022	+	+	+	+	+	+	+	+	6
5	Su et al., 2020	+	+		+	+		+	+	7
6	Jeddi et al., 2020	+	+	+	+	+	+	+	+	6
7	Brew-Sam	+	+	+	+	+	+	+	+	8



	et al., 2020										
8	Huang et al., 2023	+	+	+	+	+	+	+	+	+	8
9	Humble et al., 2016	+	+	+	+				+	+	6
10	Conway et al., 2017	+	+	+	+			+	+	+	7
11	Trawley et al., 2017	+	+	+	+				+	+	6
12	Rafiullah and David, 2019	+	+	+	+	+	+	+	+	+	8
13	Ernsting et al., 2019	+	+	+	+	+	+	+	+	+	8
14	Boyle et al., 2017	+	+	+	+				+	+	6
15	Zhang et al., 2019	+	+		+	+	+	+	+	+	7
16	Ohno et al., 2016	+	+	+	+				+	+	6

3.3. Patients' adoption level of mHealth apps for diabetes self-management

The prevalence of mHealth app adoption ranged from 7% (Conway et al., 2017) to 47% in a study conducted by Su et al. (2020) in China. The adoption level of mHealth apps was 36.62% among patients in Saudi Arabia (Rafiullah and David, 2019), which is higher than the adoption levels reported by Ernsting et al. (2019) at 25%, Boyle et al. (2017) at 19.6% and Zhang et al. (2021) at 15.4%. A qualitative study by Abd-alrazaq et al. (2021) revealed that a high adoption level of a diabetes self-management app was followed by decreased use upon having stable blood sugar levels and insulin doses.

3.4. Factors associated with patients' adoption of mHealth apps for diabetes self-management

This section focuses on the determinants of patients' adoption or use of mHealth apps for diabetes self-management. The factors comprise barriers and facilitators of adopting mhealth apps, which were further categorized into subsections: patients' demographics, preferred app features or functionalities, and perspectives and experiences. In addition, the prevalence of the identified factors is documented.

3.4.1. Patient demographics and diabetes-related characteristics

The patients' characteristics found to influence the adoption of mHealth apps for DSM included age group, gender, educational level, household income, and competency in technology use. As shown in Table 1, most studies (35%) reported that older patients were less likely to use DSM mHealth apps relative to younger patients (Humble et al., 2016; Conway et al., 2016; Rafiullah and David, 2019; Ernsting et al., 2019; Mathiesen et al., 2017; Zhang et al., 2019). DSM app usage was higher among female patients and those with higher educational qualifications compared to male patients (Rafiullah and David, 2019; Ernsting et al., 2019) and those with lower educational levels (Zhang et al., 2019), respectively. Users with higher eHealth literacy and competency in using information technology for health demonstrated higher odds of adopting DSM apps (Ernsting et al., 2019). A recent study by Zhang et al. (2019) also found that diabetes apps were more adopted by patients with relatively higher monthly incomes.

Some of the aforementioned findings are supported by a number of qualitative studies (Abd-alrazaq et al., 2021; Jain et al., 2019; Yu et al., 2022). For instance, language barriers, the presence of numerous unnecessary notifications, and challenges for older populations and those with a low literacy level were highlighted as shortcomings of a diabetes self-management app, Droobi (Abd-alrazaq et al., 2021). In terms of technology use, patients who were smartphone users (Humble et al., 2016; Conway et al., 2016) or found apps easy to use demonstrated higher odds of using mHealth apps (Jeffery et al., 2019; Brandt et al., 2019; Boyle et al., 2017), while the adoption rate was significantly increased upon training patients on how to use mHealth apps (Pludwinski et al., 2016; Trawley et al., 2017; Brandt et al., 2019). Likewise, the adoption of DSM apps was affected by the frequency of blood glucose monitoring, duration of diagnosis, physical activity, and diabetes control. A few studies found that newly diagnosed patients and those engaging in regular physical activity and monitoring their blood glucose levels were more likely to use DSM mHealth apps (Trawley et al., 2017; Ernsting et al., 2019). In contrast, there were lower odds of adopting DSM apps among patients without diabetes-related complications (Jeffery et al., 2019).

Table 3 Summary of assessment for quality appraisal and risk of bias in the qualitative studies included in this review based on Spencer and colleagues' appraisal criteria.

		Abd- alrazaq et al., 2021	Pludwinski et al., 2016	Kelly et al., 2018	Yu et al., 2022	Torbjørnsen et al., 2019	Brandt et al., 2019	Jain et al., 2019	Jeffery et al., 2019	Mathiesen et al., 2017	Peng et al., 2016	Jacobs- Basadien et al., 2022
How well-defended is the sample design/target selection of cases/documents?	Discussion of study locations/areas and how and why they were chosen	+	+		+	+	+	+	+	+	+	+
	Description of the population of interest and how sample selection related to it (e.g., typical, extreme case, diverse constituencies, etc.)	+	+	+	+	+	+	+	+	+	+	+
	Rationale for the basis of selection of the target sample/settings/documents (e.g., characteristics/features of target	+	+		+	+	+	+	+	+	+	+
	sample/settings/documents, basis for inclusions and exclusions, discussion of sample size/number of cases/setting selected, etc.)											
	Discussion of how sample/selections allowed needed comparisons to be made	+		+	+			+	+	+		+
Sample composition/case inclusion – how well is the eventual coverage described?	Detailed profile of achieved sample/case coverage	+	+	+		+	+		+	+	+	+
	Maximum inclusion (e.g., language matching or translation, specialized recruitment, organized transport for group attendance)											
	Discussion of any missing coverage in achieved samples/cases and implications for study evidence (e.g., through comparison of target and achieved samples, comparison with population, etc.)	+			+			+	+			+
	Documentation of reasons for nonparticipation among sample		+	+			+	+		+		+
	approached/noninclusion of selected cases/documents											
Discussion of access and methods of approach and how these might have affected participation/coverage	+		+	+	+	+		+	+	+		
	Total Scores	7	5	5	6	5	5	7	6	6	5	7

Qualitative studies revealed that support provided by family members improved patients' adoption level of diabetes self-management apps. For instance, despite having a low literacy level, patients were able to upload their data through the support provided by their children (Abd-alrazaq et al., 2021; Yu et al., 2022).

3.4.2. Patients' perspectives, experiences and perceptions

The majority of studies revealed that patients perceived their self-management as adequate, thus indicating that the use of mhealth apps was unnecessary. Furthermore, these patients were indifferent to the advantages of DSM apps (Peng et al., 2016; Trawley et al., 2017; Boyle et al., 2017). Meanwhile, 2 articles entailing focus-group discussions and in-depth interviews revealed that participants were not interested in using DSM apps since they had to be fully responsible and accountable for their self-management behaviors (Peng et al., 2016; Mathiesen et al., 2017). The preference for direct and face-to-face interaction was reported as the main reason for not using DSM apps in another 2 studies (Humble et al., 2016; Mathiesen et al., 2017). On the other hand, recommendations by healthcare professionals or other patients increased the odds of DSM app usage among diabetic patients (Peng et al., 2016; Jeffery et al., 2019; Rafiullah and David, Zhang et al., 2019).

Patients' experiences with DSM apps also affected their current or future use. Some of the predominant barriers were constraints with data entry or difficulties in integrating the app with routine (Peng et al., 2016; Kelly et al., 2018) and being unaware of the existence of such apps (Jeffery et al., 2019; Trawley et al., 2017).

3.4.3. Preferred App features and functionalities

The third section on the factors influencing DSM app usage among diabetes patients is linked to the features and functionalities of mHealth apps. Specifically, the findings reflect the desired app characteristics and functions that encouraged patients to use the DSM app and incorporate such features into their routine self-management activities. Most studies reported features and functionalities related to nutrition and diet (75%) (Humble et al., 2016; Peng et al., 2016; Kelly et al., 2018; Zhang et al., 2019), blood glucose monitoring (60%) (Rafiullah and David, 2019; Zhang et al., 2019), and physical activities such as pedometers, tracking and exercise reminders (50%) (Humble et al., 2016; Trawley et al., 2017; Torbjørnsen et al., 2019; Zhang et al., 2019). The most preferred mHealth apps entailed medication management features such as tracking, reminders and insulin calculators, followed by weight management and mental health functions and weight management functions (Brandt et al., 2019; Boyle et al., 2017; Zhang et al., 2019). Sleep patterns and appointment reminders were preferred in a few studies (Ernsting et al., 2019; Boyle et al., 2017; Jeffery et al., 2019). Patients' suggestions on how to improve mHealth apps for diabetes management focused on how to facilitate easy use and data entry.

Several studies also revealed that the odds of patients' usage of DSM apps increased if they assisted in communicating with healthcare professionals (50%) and patients (Peng et al., 2016; Rafiullah and David, 2019; Brandt et al., 2019). This finding was reflected in a qualitative study, whereby patients shared their views on the advantages of mHealth apps, such as being less time-consuming and facilitating follow-ups and communication with clinicians. The following verbatim comments were derived from the study (Abd-alrazaq et al., 2021). Appealing physical appearance (Brandt et al., 2019; Torbjørnsen et al., 2019), being easy to use (Zhang et al., 2019), ensuring data security and privacy (Rafiullah and David, 2019) and being easy to understand (Ernsting et al., 2019), providing instant feedback (Torbjørnsen et al., 2019), and enabling goal setting (Kelly et al., 2018) increased the likelihood of using DSM apps. Furthermore, DSM apps that provide vital information about diabetes, current trends and research findings (Peng et al., 2016; Jeffery et al., 2019), broad access to patient medical history (Ernsting et al., 2019) and specific information on the detection and management of hypoglycemia (Trawley et al., 2017) were more likely to encourage patient adoption and use. In contrast, issues relating to app technicality and frequent service disruption were barriers to DSM app usage (Conway et al., 2016; Brandt et al., 2019).

4. Discussion

This study entailed a systematic review of patients' adoption level of diabetes self-management mobile apps and the associated factors. The importance of the identified factors in encouraging or reducing the adoption of such apps was also investigated. Although a few similar reviews have been reported previously, this study is the first attempt to focus on the adoption level and determinants of mobile apps for diabetic patients' self-management. Patients' adoption levels differed between studies, ranging from 10% to 60%, in developing and developed countries. These differences might be linked to several factors relating either to the patients or healthcare workers, as well as sociocultural and environmental factors.

Diverse patients' sociodemographic profiles, including age, educational level, and income level, were found to influence the use of diabetes self-management apps. The adoption level was higher among younger and female patients compared to older and male patients, respectively (Bol et al., 2018, Shen et al., 2017; Lupton and Maslen, 2019). Younger patients are more inclined to use mobile apps since they provide several social media platforms that may interest them, whereas older patients are less involved in health apps and digital technologies (Isakova et al., 2016). Nevertheless, acknowledging the importance of disease and the risk involved might influence the use of disease self-management apps.

Older patients are more likely to be sensitive to the risk of diabetes-related complications, which may encourage them to use mobile health apps. Moreover, COVID-19 highlighted that older patients can effectively use and interact with mobile health apps that are tailored toward their needs (Banskota et al., 2020). Given the high prevalence of diabetes among older patients, they are pertinent in interventions targeted to enhance diabetes self-management behaviors (Paiva et al., 2020). Despite the risk of decline in cognitive function and motor skills in aged patients, incorporating patients' technological age is equally important when considering the adoption of self-management mobile apps (Harris et al., 2016).

Our review also revealed that educational level, eHealth literacy, and technical skills influenced the use of diabetes self-management apps among patients (Hong et al., 2017). These findings are unsurprising since most apps are designed using smart features and functionalities that require a certain level of education and exposure before they can be successfully operated. Technical skills are also needed to navigate the features and resolve any issue relating to data recording and sharing. Patients lacking these technical skills may be discouraged from using mobile health apps for self-management. Digital experiences and perceptions were also reported as determinants of using diabetes self-management apps (Alvarado et al., 2017; Baptista et al., 2020), which is consistent with results from other similar studies on the management of hypertension and cardiovascular diseases (Wei and Omar, 2017). Experiences relating to difficulties with data entry and integrating the app with routine daily activities might contribute to this finding (Scheibe et al., 2015; Torbjørnsen et al., 2019). A few studies demonstrated that newly diagnosed patients had higher odds of using diabetes self-management apps (Baptista et al., 2020). One reason for this finding could be that patients become frustrated with the mobile app content as their diabetes management experience increases with time.

One of the significant determinants of patients' use of diabetes self-management apps was direct recommendations by healthcare professionals (Rossman et al., 2019). This event is more likely to be triggered when there is a good patient-healthcare professional relationship and trust, which are key in encouraging patients to adhere to clinicians' recommendations. Meanwhile, the likelihood of healthcare professionals recommending mobile health apps is also influenced by the apps' characteristics and their experiences with such digital technologies (Machleid et al., 2020). Nevertheless, studies exploring healthcare professionals' recommendations for diabetes self-management apps and their incorporation into care pathways are limited. The data paucity and lack of robust empirical evidence and consensus regarding the assessment methods are some of the reasons for clinicians' drawbacks in recommending diabetes self-management apps.

Most of the predictors identified in this review were hypothesized as constructs of well-established technology adoption theories, such as the TAM (Davis, 1993), diffusion of innovation theory (Rogers, 2003), and the unified theory of acceptance and use of technology (Venkatesh and Davis, 2000). These findings reflect the comparative benefits of apps in diabetes self-management, as well as their ease of use and compatibility with daily routine.

Specific features that facilitate interaction with mobile health apps and assist in weight reduction, medication management and maintaining a healthy lifestyle were preferred by T2DM patients (Jain et al., 2017; Bonet Olivencia et al., 2021). Thus, patients prioritize mobile apps that are beneficial and tailored toward their self-management goals. Similar results were reported in a systematic review by Alaslawi et al. (2022), which focused on both patients' and healthcare providers' views and recommendations regarding diabetes self-management apps. Other factors influencing use were security, privacy and costs, which also align with the findings from previous reviews on diabetes-related applications (Adu et al., 2018) and developing apps for diabetes (Doyle-Delgado and Chamberlain, 2020) and other chronic diseases (Birkhoff et al., 2017).

5. Final Considerations

This study involved a comprehensive systematic literature search and identification of relevant and recent articles on mHealth app adoption and the associated factors among diabetes patients for self-management. In-depth information on patients' perspectives and awareness of mHealth apps for diabetes self-management was gleaned from this review, thereby providing up-to-date findings on the aforementioned topic. Thematic and empirical analyses were also performed to obtain robust data from the various research designs employed in the articles and to achieve data triangulation.

Nevertheless, this study is not without limitations. The literature search was restricted to four databases and focused on diabetes patients and end-users, whereas other pertinent stakeholders, such as healthcare professionals, app developers, and policymakers, were not considered the target groups. As a result, the generalisability of the findings is limited since no inference could be deduced regarding healthcare personnel and mHealth app developers' perspectives. Some of the studies included reported the use of mHealth apps among diabetes patients and those with other chronic illnesses. This made it challenging to separate the data based on the type of diabetes and other comorbidities.

In conclusion, diabetes self-management is crucial to reduce the risk of complications and improve management outcomes. Mobile health apps are promising digital technologies that could facilitate diabetes self-management when used by patients. Apart from addressing the factors that may influence the adoption and actual usage of these technologies, specific features desired by patients also need to be considered. More research is needed to elucidate how mobile health apps can be effectively integrated into diabetes care and management pathways.

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Ethical considerations

Not Applicable

Conflict of Interest

The authors declare no conflicts of interest.

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