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Diabetes Self-management Intervention Based Smartphone Application in Patients With Diabetes Mellitus: Systematic Review

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ABSTRACT
Diabetes is a debilitating health condition that's rapidly increasing in prevalence globally. Patients with diabetes require education about the disease to improve their knowledge, in which smartphone applications help improve diabetes care and self-management. This study aims to determine the effectiveness of smartphone application-based self-management interventions in diabetes mellitus patients. Five online databases (Science direct, Scopus, ProQuest, Springer Link and SAGE) was employed. Studies published in English from 2015-2021 were considered. Only randomized controlled trials of application-based self-management intervention in patients with diabetes mellitus. Total of 374 articles were found and ten studies were selected in this systematic review. There are many diabetes related mobile apps like Diaguru, Calendar App, Sidekick Health, Bluestar, GlycoLeap that mainly focusing on self-management of diabetes, lifestyle modification, and medication adherence motivation. Smartphone application-based diabetes self-management intervention have beneficial effects on self-efficacy, self-care activities, quality of life and clinical outcomes for diabetes mellitus patient.

Keywords: Self-Management, Self-Care, Diabetes Mellitus, Smartphone, Application

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BACKGROUND

Diabetes is a debilitating health condition that is rapidly increasing in prevalence globally. The global prevalence rate of diabetic adults in 2000 was 115 million, which tripled to 466 million in 2019 and continues to increase. It is expected to reach 578 million by 2030, with an estimated 700 million by 2045 (IDF, 2019). The prevalence of diabetes patients in Indonesia reaches 6.2 percent, which means that more than 10.8 million people suffer from diabetes by 2020. This figure is estimated to increase to 16.7 million patients on 2045 (PERKENI, 2019). This chronic disease requires ongoing management to avoid various complications such as arteriosclerosis, heart disease, renal failure, peripheral neuropathy, retinopathy, and foot ulcers (American Diabetes Association, 2020).

The prevention of diabetic complications requires not only medication but also self-management, all people with diabetes should participate in diabetes self-management education with a focus on self-care, empowerment, and support from healthcare professionals. Patients with diabetes require education about the disease aimed at improving their knowledge and skills. Patients with good knowledge able to control the disease, make informed decisions, encourage self-care and increase active engagement with professionals which leads to improved health and quality of life (Hilmarsdóttir et al., 2020).

Good self-management in diabetes mellitus results in a more than 0,4% reduction in glycated hemoglobin (Essien et al., 2017;Tay et al., 2021). Traditionally, self-management support for diabetic patients comprised of face-to-face patient education using leaflet or video. However, the majority of patients with diabetes continue to have low adherence to self-care activities and related health outcomes. Which indicate that such measures are insufficient to encourage self care management (Aminuddin et al., 2019). To improve the outcome of this problem self-management programs for type 2 diabetes mellitus are available through smartphone technology.

Smartphone technology opens the opportunity to address the persistent challenge of providing continuous and ongoing care in chronic diseases, including Diabetes Mellitus. Integrating m-Health into public health practice as a strategy to monitor chronic disease is paramount in upcoming years. As increases in health expenditures are incurred due to an ageing population and increasing prevalence of chronic disease and comorbidity (Kelly et al., 2020). Health interventions based on smartphone applications help improve quality of life, self-efficacy, self-care activities, and health-relevant outcomes for type 2 diabetes mellitus patient (Sunil Kumar et al., 2020; Kusnanto et al., 2019; Hilmarsdóttir et al., 2020; Agarwal et al., 2019). This systematic review aims to determine the effectiveness of smartphone application-based self-management interventions in diabetes mellitus patients.

METHOD

To develop the systematic review, a review protocol was prepared to guide the review process. The protocol covered the rationale and objectives of the review, the eligibility criteria for pooled studies, sources of information, the search strategy, the study selection and data collection processes, the data items and outcomes sought, the method for assessing the risk of bias of each pooled studies.

Search Strategies

A systematic literature search was done by using five electronic databases: Science Direct, Scopus, ProQuest, Springer Link and SAGE. These databases cover the biomedical, life and physical sciences, behavioural and social science the arts and the humanities and information science. The search was conducted in February 2021. The keywords and

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medical subject headings (MeSH) term used were 'diabetes mellitus', 'diabetes mellitus type 2', 'self-management', 'self-care', and 'smartphone. They were combined using Boolean operators 'AND' and 'OR' to locate relevant studies. Both published and unpublished studies were searched during the search process. Finally, the reference lists of the identified studies were reviewed to identify additional articles.

Inclusion and Exclusion Criteria

Only randomized controlled trials published in English were included in this review to provide the most robust evidence of the intervention effects. The other inclusion criteria were based on the aims of the review. The study participants were adult patients who were age 18 years and above with a confirmed diagnosis of type 2 diabetes mellitus. The studies evaluated the effectiveness of smartphone application-based diabetes self-management intervention. The studies separated participants into at least one group receiving smartphone-based self-management interventions and one group receiving usual care or with no smartphone-based intervention. Studies that explored at least one of the following outcomes: self-efficacy, self-care activities, Health related quality of life and clinical outcomes, such as glycated hemoglobin. Only studies published from 2015 to 2021 were included. We excluded studies that used qualitative data as an outcome measure, were not written in English, and did not use smartphone-based technology for diabetes self-management purposes.

Study selection

According to the PRISMA guideline, potential studies were first retrieved from the electronic databases. After removal of duplicates, the titles and abstracts of the potential studies were screened for eligibility. The full text of each selected study that met the inclusion criteria was retrieved for further examination. A secondary search was performed of the studies' reference lists to identify additional records. Finally, relevant studies that met all of the inclusion criteria were included in the systematic review. The search and screening processes were performed by two independent reviewers. Any disagreements were resolved by a third reviewer.

Risk of Bias

The JBI critical appraisal checklist was used to assess the methodological quality of the included randomized controlled trials. risk of bias was assessed by 13 items: Was true randomization used for assignment of participants to treatment groups. Was allocation to treatment groups concealed. Were treatment groups similar at the baseline. Were participants blind to treatment assignment. Were those delivering treatment blind to treatment assignment. Were outcomes assessors blind to treatment assignment. Were treatment groups treated identically other than the intervention of interest. Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed. Were participants analyzed in the groups to which they were randomized. Were outcomes measured in the same way for treatment groups. Were outcomes measured in a reliable way. Was appropriate statistical analysis used. Was the trial design appropriate, and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial. Each domain is assessed as a high, low, or unclear risk of bias according to the assessment criteria stated in the tool, if there are articles with a high risk of bias it can be excluded (Joanna

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Briggs Institute, 2020). Three independent reviewers assessed the risk of bias for each included study. Any disagreements were resolved by discussion.

Data Extraction

A structured form is used to extract information from the articles included, starting from the author, year, country, design, sample, intervention and outcome of the article are used to evaluate the effect of the intervention

RESULTS

Study Selection

A total of 374 articles were identified. After removal of duplicates, the titles and abstracts of 27 articles were reviewed for eligibility. After the further exclusion of 290 articles, the full texts of 10 articles were retrieved and reviewed. Finally, 10 articles were included in the systematic review after the application of the inclusion and exclusion criteria

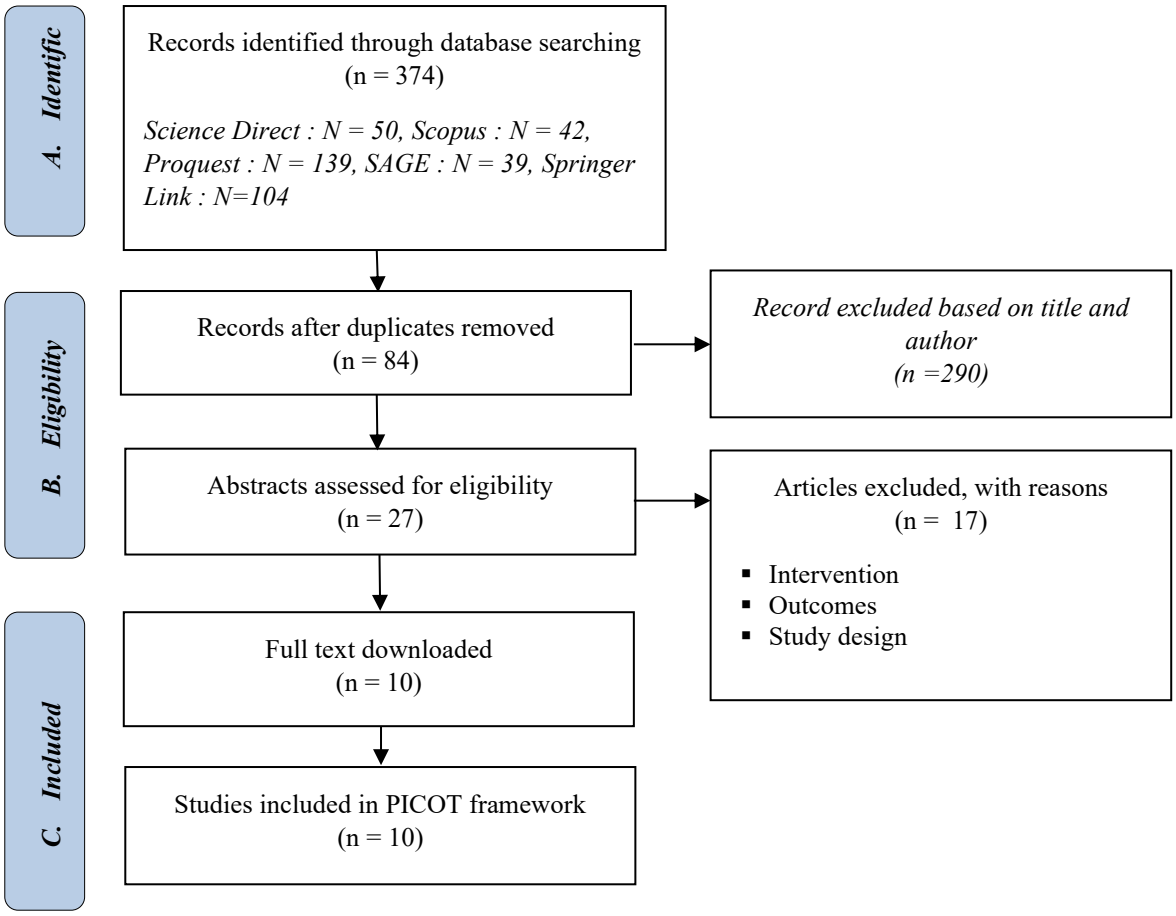

Figure 1. Flow chart

Risk of Bias

10 articles were assessed for risk of bias using the JBI critical appraisal checklist for randomized controlled trials. The result were: score of 100% (n = 6 articles) (Sunil Kumar et al., 2020, Kusnanto et al., 2019, Agarwal et al., 2019, Kim et al., 2021, Hsu et al., 2016, Hilmarsdóttir et al., 2020. Score of 92% (n = 2 article) (Boels et al., 2019, Bailey et al., 2020) and Score 84% (n = 2) (Koot et al., 2019, Goyal et al., 2016)

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Characteristics Study

The articles used were published in 2015-2021, of the 10 selected articles one article came from Indonesia, and 9 other articles came from abroad, namely from (India=1) (Sunil Kumar et al., 2020), (Netherland=1) (Boels et al., 2019a), (Iceland= 1) (Hilmarsdóttir et al., 2020), (Canada= 2) (Agarwal et al., 2019, Goyal et al., 2016), (Singapore= 1) (Koot et al., 2019), (United Kingdom = 1) (Bailey et al., 2020), (Korea = 1) (Kim et al., 2021) and (United States= 1) (Hsu et al., 2016). The total of respondents in this review was 1198. The samples who received the intervention (intervention group) were 645 subjects while the sample in the control group were 553 subjects. Participants who were involved were limited by several criteria such as: age, own and able to operate smartphone, diagnosed with type 2 diabetes for more than 6 months and levels of HbA1c more than 7%

Table 1. Information of Characteristic Study

Author and country	Type of study	Participant	Application name	Content of application	outcome
Sunil Kumar *et al.,* 2020 India	Randomized control trial	*n= 300* G1 = 150 G2 =150	Diaguru	values of the sugar level, insulin level and the type of food intake could be given	Quality of Life
Kusnanto *et al*., 2019 Indonesia	Randomized control trial	*n= 30* G1 = 15 G2 = 15	DM calender application	blood sugar control, education program, nutri- tion therapy, and physical activity	Self-efficacy HbA1c
Boels *et al*., 2019 Netherland	Randomized control trial	*n= 230* G1 = 115 G2 = 115	The TRIGGER study	Hypoglycemia, dietary habits, physical activity, or glucose control.	HbA1c Quality of Life
Hilmarsdóttir *et al*., 2020 Iceland	Randomized control trial	*n= 37* G1 = 18 G2 = 19	Sidekick Health app	nutrition, physical activity, stress management and clinic.	Quality of Life
Agarwal *et al*., 2019 Canada	Randomized control trial	*n= 223* G1 = 110 G2 = 113	BlueStar mobile app	baseline health, daily blood glucose readings, exercise activity, and food intake.	HbA1c Quality of Life Self-Care Activities Self-efficacy
(Koot *et al*., 2019) Singapore	Single-Arm Feasibility Study	n= 100	GlycoLeap	diabetes and self-management, blood glucose monitoring, weight monitoring, meal logging, physical activity tracking, health coach	HbA1c
Bailey *et al*., 2020 UK	Randomized control trial	*n= 20* G1 = 10 G2 = 10	MyHealth Avatar	goal-setting, action planning, review behaviour goals,	sitting, standing, stepping
Kim *et al*., 2021 Korea	Randomized control trial	*n= 68* G1 = 32 G2 = 36	Doctor Diary	self-management behaviors such as self-measuring blood sugar, taking medication, following a diabetic diet, and exercising	HbA1c BMI fasting blood sugar levels health behaviors
Hsu *et al*., 2016 US	Randomized control trial	*n= 40* G1 = 20 G2 = 20	Collabo-Rhythm	the development of self-efficacy in diabetes care	HbA1c
Goyal *et al*., 2016	Randomized control trial	*n= 150*	The bant2 app	lifestyle behaviors with their glycemic control through paired	HbA1c

Canada	(pre- and post-prandial) blood glucose testing	Self-Care Activities Body mass Index Blood Glucose

Description of the interventions

The studies included in this review categorized into four main types: 'education' (provision of diabetes-related and self-care education), 'reminders' (reminders to carry out specified self-care activities), 'self-monitoring' (monitoring and recording of self-care data obtained) and 'feedback' (provision of feedback or healthcare recommendations based on the self-care data input either by healthcare professionals). Eight studies used smartphone application interventions (Sunil Kumar et al., 2020; Kusnanto et al., 2019; Hilmarsdóttir et al., 2020; Agarwal et al., 2019; Koot et al., 2019; Bailey et al., 2020; Kim et al., 2021; Goyal et al., 2016) and two study used both smartphone application and regular SMS intervention (Hsu et al., 2016; Boels et al., 2019).

The duration of smartphone application-based diabetes self-management intervention were given as follows for two months (n=2) (Bailey et al., 2020; Kim et al., 2021), for 3 months (n=2) (Kusnanto et al., 2019; Hsu et al., 2016), for 4 months (n=1) (Hilmarsdóttir et al., 2020), for 6 months (n=4) (Sunil Kumar et al., 2020; Boels et al., 2019; Agarwal et al., 2019; Koot et al., 2019), and for 12 months (n=1) (Goyal et al., 2016).

Effectiveness of interventions on health-related Quality of Life

Four studies measured health-related quality of life for the intervention and control groups. Each using 3 different tools. WHO QOL BREF Questionnaire (Sunil Kumar et al., 2020), Icelandic health-related Quality of Life scale (IQL-test), a 32-item scale (Hilmarsdóttir et al., 2020), the Audit of Diabetes Dependents Quality of Life (ADDQoL) consists of 19 diabetes-specific items (Boels et al., 2019b), and the EuroQol-5D (EQ-5D) (Agarwal et al., 2019). The study measuring the change in health-related quality of life by comparing the use of smartphone-based self-management interventions between two groups. The effect was statistically significant (Sunil Kumar et al., 2020).

Effectiveness of interventions on Self-efficacy

Two studies measured self-efficacy scores of the intervention and control groups. One study used diabetes management self-efficacy scale (DMSES), consisting of 15 questions (Kusnanto et al., 2019), another study used self-efficacy measured using 2 validated scales for diabetes, the Problem Areas in Diabetes and the Summary of Diabetes Self-Care Activities (Agarwal et al., 2019). Education with DM calender application has increased the perception of self-efficacy and improved the behavior of good self-management (Kusnanto et al., 2019).

Effectiveness of interventions on Self-care Activities

Two studies assessed the self-care activities post smartphone application-based intervention. Diabetes self-care behaviors (measured by PAID and Summary of Diabetes Self-Care Activities-6) (Agarwal et al., 2019), another study used Summary of Diabetes Self-Care Activities (SDSCA) measure. The SDSCA is an 11-item instrument that assesses individual levels of diabetes self-care, focussing on general diet, specific diet, exercise, medication adherence, blood-glucose testing, smoking, and foot care (Goyal et al., 2016).

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Effectiveness of interventions on Glycated hemoglobin (HbA1c)

Seven studies included in this review reported glycated hemoglobin levels. HBA1c laboratory tests were performed before and after self-management intervention based smartphone application (Kusnanto et al., 2019; Boels et al., 2019b; Agarwal et al., 2019; Koot et al., 2019; Kim et al., 2021; Hsu et al., 2016; Goyal et al., 2016). A cut-off glycated hemoglobin level of 8% was chosen, as the ADA recommended an HbA1c goal of < 8% for patients with more severe diabetes (ADA, 2017). The effect of smartphone-based interventions on reduction in glycated hemoglobin was statistically significant.

DISCUSSION

This systematic review discusses smartphone application-based diabetes self-management intervention. Smartphone applications are more prone to technical issues such as software glitches and restricted access due to the need for a stable wireless connection, which can be major barriers to effective distant health interventions (Alvarado et al., 2017). Moreover, it was also observed that studies with intervention duration of less than six months increase the likelihood of remembering and applying what was learned, thus increasing confidence and motivation in managing their condition (Sunil Kumar et al., 2020).

Smartphone application-based diabetes self-management intervention have effect on glycemic control (Agarwal et al., 2019; Koot et al., 2019; Boels et al., 2019; Kusnanto et al., 2019). Participants with glycated hemoglobin levels of less than 8% at baseline showed large improvements in self-efficacy. This implies that patients with better glycemic control at baseline benefitted more from the smartphone applications (AADE, 2017; Kusnanto et al., 2019). Individuals with glycated hemoglobin levels > 8% are more likely to already have diabetic complications that can affect their ability to adhere to self-care activities (American Diabetes Association, 2020). These individuals may be less motivated, and possible past failures in adhering to self-care activities can lower personal mastery expectations of their ability in carrying out those activities.

In this review, self-care activities showed improvement with smartphone-based self-management interventions. This is attributed to behavioral change techniques providing feedback on performance and education on consequences of behavior in the smartphone-based self-management interventions. Prompting self-monitoring behavior are the main techniques associated with improvement of health behaviors (Hsu et al., 2016). Smartphone-based interventions have the advantage of being easy to use and widely accessible, and thus can keep patients engaged longer, increasing their effectiveness on self-care activities (Agarwal et al., 2019). In addition, the improvement in self-care activities reported can also be associated with an increase in self-efficacy. Self-efficacy enables people to trust themselves and to use their skills to overcome any challenges faced, leading to successful adherence to self-care activities in type 2 diabetes mellitus (Kim et al., 2021).

Self-efficacy also reduces fear and distress in diabetes management, which is commonly measured in diabetes-related quality of life tools, resulting in the improved quality of life (Boels et al., 2019a). More studies are needed to confirm the effectiveness of smartphone-based self-management interventions on health-related quality of life. Smartphone-based self-management interventions were also found to reduce glycated hemoglobin levels for patients with type 2 diabetes mellitus. This can be attributed to the self-care domains that were targeted in the interventions, such as medication adherence, diet, and physical activity, which has been found to improve glycemic control and HbA1c levels (ADA, 2017) Furthermore, greater self-efficacy is also associated with lower glycated hemoglobin levels,

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as self-efficacy improves patients' understanding of their condition and increases their motivation to manage their diabetes better (Kusnanto et al., 2019).

CONCLUSION

Smartphone applications-based diabetes self-management have been shown to positively improve the outcomes, including HbA1c levels, self-efficacy, self-care activities, quality of life. Today, the need for individualized care for patients with diabetes is more evident that ever, a validated evidence-based guidance should be established for the selection of the most suitable mobile based diabetes app. However, more research with rigorous study design is needed to evaluate the effectiveness of smartphone application-based diabetes self-management intervention in patients with diabetes mellitus.

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CONFLICT OF INTEREST

There was no conflict of interest

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