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Online diabetes self-management education application for reducing glycated hemoglobin level among patients with type 1 diabetes mellitus: a systematic review and meta-analysis

Sahebeh Usefi[1], Fereshteh Davoodi[2], Atefeh Alizadeh[3] and Mehrshad Mohebi Far[4*]

Abstract

Background This meta-analysis study aims to evaluate the Diabetes Self-Management Education and Support (DSMES) online application for reducing glycated hemoglobin levels among patients with type 1 diabetes mellitus (T1DM) patients.

Main text The Web of Science (WoS), Cochrane Library, PubMed, Scopus, PROSPERO, and EMBASE databases were searched with Medical Subject Headings (MeSH) terms without minimum time limitation until February 2024. To be eligible, all the following predefined inclusion criteria must have been met in the original randomized controlled trial (RCT) studies without language limitation including T1DM, patients, online digital interventions such as web-based, mobile health applications, or e-health, 3 or more months follow-up, and measuring HbA1c. Finally, 10 studies were conducted, 1195 T1DM patients were included in this study of which 421 (35.2%) were adults and 774 (64.8%) were adolescents. Overall, the mean differences for HbA1c at 6 months between baseline and follow-up groups was 0.27% (-0.76, 1.31) ($P<0.001$) in adultescents and 0.92% (0.34, 1.5) ($P<0.001$) in adults. Moreover, the mean differences for HbA1c at 12 months between baseline and follow-up groups was −0.02% (-0.31, 0.26) ($P=0.85$) in adults.

Conclusions Online DSME is effective in improving the glycemic control of adults and adultescents individuals with T1DM for reducing HbA1c while maintaining this important factor at an appropriate dose.

Keywords Diabetes mellitus, Type 1, Diabetes self-management education, Hemoglobin A1c

*Correspondence:
Mehrshad Mohebi Far
mehryasi22@gmail.com
[1]School of Nursing and Midwifery, Babol University of Medical Sciences, Babol, Mazandaran, Iran
[2]Faculty of Nursing and Midwifery, Tehran University of Medical Sciences, Tehran, Iran
[3]Ramsar School of Nursing, Babol University of Medical Sciences, Mazandaran, Iran
[4]Student Research Committee, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

Introduction

Type 1 diabetes mellitus (T1DM), which is generally known as Insulin-dependent diabetes mellitus (IDDM) [1], is caused by insulin deficiency due to the destruction of the beta cells of the pancreas in the early stages of autoimmunity that usually occurs in adolescence [2]. In these patients, lack of insulin secretion or decrease in insulin function leads to carbohydrate, fat, and protein metabolism disorders [3]. Approximately 8.4 million people in the world are expected to be living with T1DM by 2021, of which 500,000 new cases will occur that year [4]. The number of people living with T1DM is expected to increase from 13.5 to 17.4 million by 2040 [4, 5]. Recent evidence shows that longer periods of hyperglycemia and duration may be more important for brain development as opposed to hypoglycemia episodes [6]. This disease can strongly affect synaptic disorders in the hippocampus area and this condition can be caused by hyperglycemia [7]. The neurotrophic factor is a critical component of the modulation of neural plasticity, which originated in the brain [8]. Moreover, the brain-derived neurotrophic factor, which regulates cell survival, proliferation, and synaptic growth in the developing and mature brain, is a member of the family of neurotrophin growth factors and plays an essential role in neuronal plasticity [9].

Diabetes Self-Management Education and Support (DSMES) is a tool to improve quality of life, reduce medical complications, and glycemic control [10]. To cope with their condition, DSMES provides patients and their families with essential information. In principle, all diabetic patients should receive quality DSMES [11], but the availability of such quality services varies between health systems in terms of accessibility and affordability of care. These challenges are addressed through digital health interventions [12]. Different forms of information technology used in healthcare, such as smartphones, are defined by the term "digital health" [13]. Digital health has proven to be successful in the DSMES, as with other areas of healthcare. Social media interventions have succeeded in improving healthcare outcomes, and some medical units are considering the use of social media to manage complex diseases [14, 15]. On the other hand, DSMES uses a wide range of online health interventions with different effects [16]. The effectiveness of Web interventions to improve different clinical and psychosocial outcomes has also been shown in the DSMES study [17, 18]. Therefore, this meta-analysis study aims to evaluate the DSMES online application for reducing glycated hemoglobin levels among patients with T1DM patients.

Methods

Design and data resource

This study was designed by The Preferred Reporting Instrument for Systematic Review and Meta-Analysis (PRISMA) [19]. The Web of Science (WoS), Cochrane Library, PubMed, Scopus, PROSPERO, and EMBASE databases were searched with Medical Subject Headings (MeSH) terms ((((((“Diabetes Mellitus, Type 1“[Mesh]) OR “Glucose Metabolism Disorders“[Mesh]) AND “Self-Management“[Mesh]) OR “Education“[Mesh]) AND “Glycated Hemoglobin“[Mesh]) OR “Glycated Serum Proteins“[Mesh]) without minimum time limitation till February 2024. M.MF and S.U. performed a subsequent search and used free text terms to combine the keywords.

Eligibility criteria

To be eligible, all the following predefined inclusion criteria must have been met in the original randomized controlled trial (RCT) studies without language limitation:

a) T1DM patients.
b) Online digital interventions such as web-based, mobile health applications, or e-health.
c) 3 or more months follow-up.
d) Measuring HbA1c.

Study selection and quality assessment

Search strategies were drafted and refined by 4 years experienced librarian, M.MF, during a team discussion. A. A and F.D. screened the studies and resolved the disputes between the evaluators through consensus (M.MF). Scientific article types that did not have interventional design (case reports, case series, observational studies, reviews, editorials, commentaries, RCT guidelines, and chapter books) were excluded. A.A., F.D., and S.U independently extracted relevant variables and characteristics using a standard sheet drawn up by the Cochrane Public Health Group. Then, the conflict between researchers was solved by M.MF. M.MF and S.U independently assessed the studies using the Cochrane Risk of Bias 2.0 tool [20]. In the Across Study, bias was evaluated using funnel graphs, forest graphs, and statistical methods. The quality was assessed based on the GRADEpro Guideline Development Tool (GDT) [21].

Summary measures

Random-effects, pooled analysis was conducted at baseline, 6 months, and 12 months using pair effects comparisons. The differences in means (MD) with 95%CI were expressed for changes in HbA1c. Use of ReviewManager (RevMan) 5.4 (The Nordic Cochrane Centre, Copenhagen, Denmark) was used for the qualitative analysis. The median and interquartile range (IQR) were converted into mean and SD. The direction of effect for HbA1c has been determined to be neutral. Therefore, an increase in the effectiveness of the study interventions was marked by a large negative MD.

Results

Study description

3,278 articles discovered which 1,916 articles removed for duplication. Then, 27 articles were removed after filtering titles and abstracts for search terms. Finally, 10 articles remaining to for the study (Fig. 1). 1195 T1DM patients were included in this study which 421 (35.2%) were adults [22–26] and 774 (64.8%) were adolescents [27–31].

Pre-intervention HbA1c

Overall, the means differences for HbA1c with I^2 28% at the baseline between control and intervention groups was 0.12% (-0.04, 0.28) (P=0.18) (Fig. 2), I^2 41% at the baseline between control and intervention groups in adults 0.11% (-0.13, 0.35) (P=0.15) (Fig. 3), I^2 68% at the baseline between control and intervention groups in adults 0.03% (-0.32, 0.38) (P=0.01) (Fig. 4).

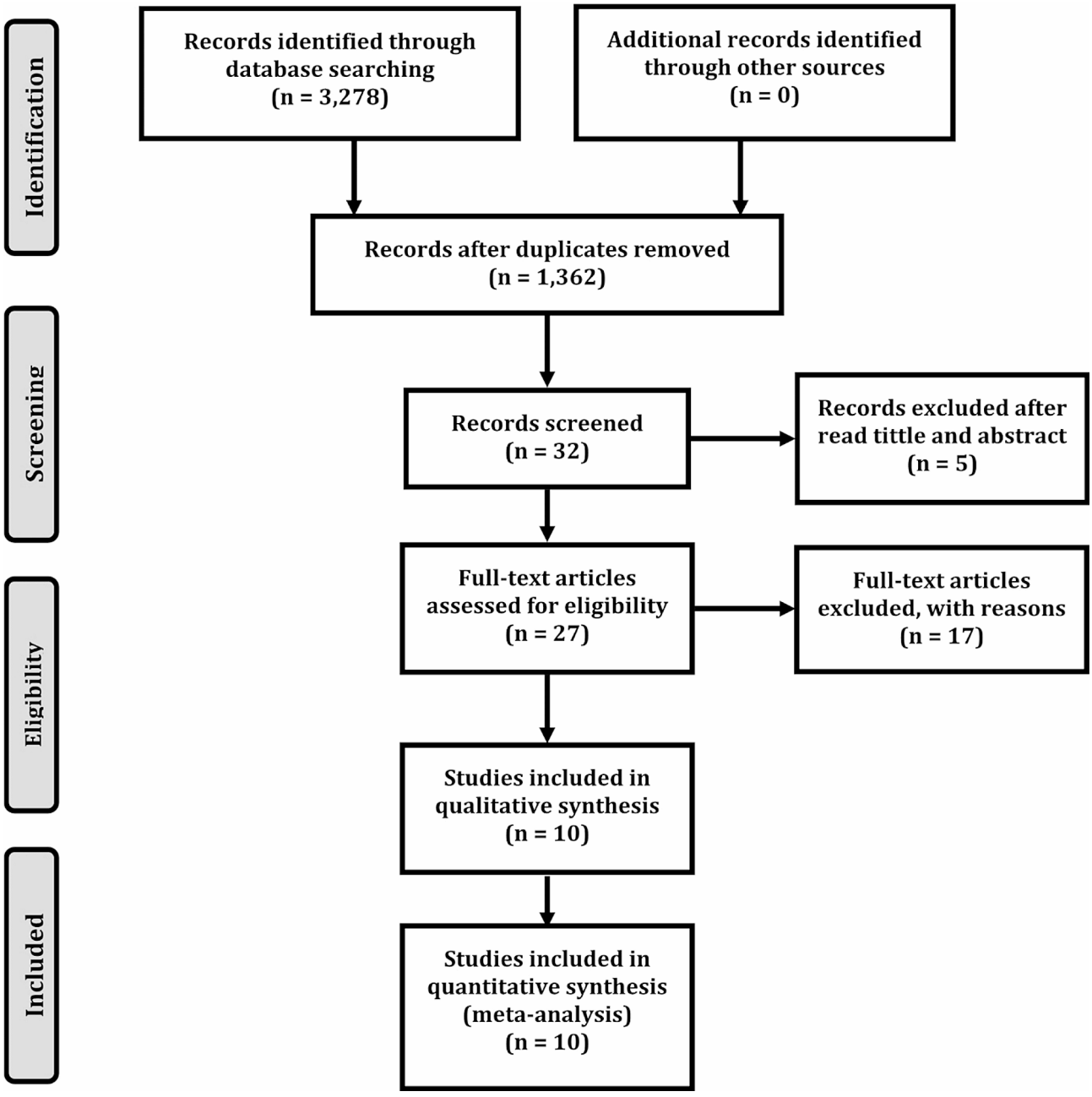

Fig. 1 Study Flow Diagram showing how to extract articles

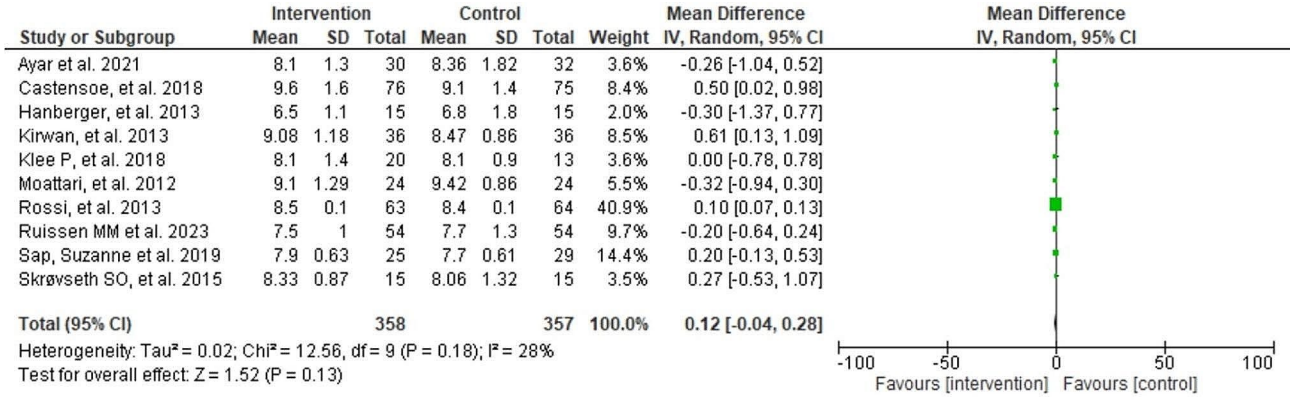

Fig. 2 Overall pre-intervention HbA1c

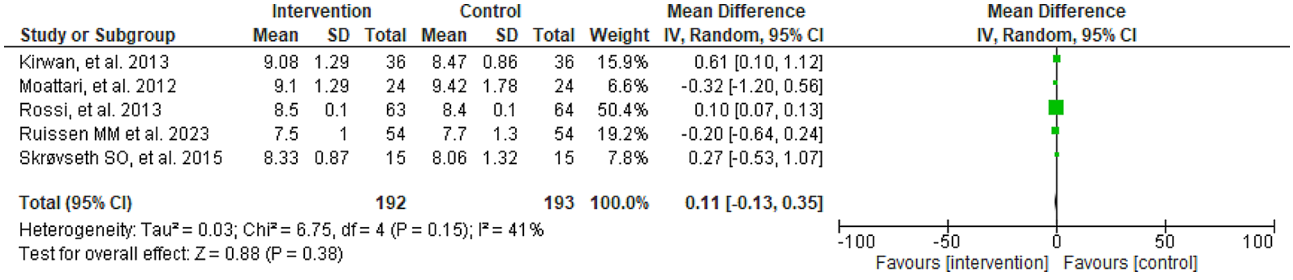

Fig. 3 Pre-intervention HbA1c in adults

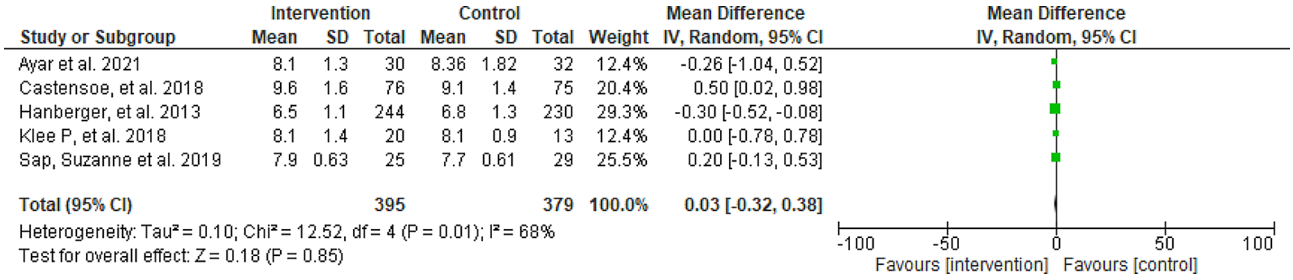

Fig. 4 Pre-intervention HbA1c in adolescents

HbA1c at 6 months

Overall, the means differences for HbA1c with I^2 99% at 6 months between baseline and follow-up groups was 0.27% (-0.76, 1.31) ($P<0.001$) (Fig. 5), I^2 90% at the 6 months between baseline and follow-up groups in adults 0.92% (0.34, 1.5) ($P<0.001$) (Fig. 6).

HbA1c at 12 months

Overall, the mean difference for HbA1c with I^2 0% at 12 months between baseline and follow-up groups was −0.02% (-0.31, 0.26) ($P=0.85$) in adults (Fig. 7).

Risk of bias

6 (60%) studies had low risk of bias [23, 25–27, 30, 31]. 2 (20%) studies were judged as low risk of bias [22, 29], and other studies (20%) were judged as unclear risk of bias [24, 28] (Table 1, **and** Fig. 8).

Discussion

This meta-analysis study showed that online-led DSME application has more benefits than the traditional treatment for both adults and adultescents with T1DM and after 6 months follow-up the HbA1c was reduced in both groups. This study didn't show a significant improvement after 12 months of intervention compared to the baseline.

Some clinical evidence showed that DSME online applications are effective in improving glycemic in individuals with T1DM [22, 23, 25, 26, 30, 31]. However, there was no significant reduction in HbA1c after intervention online applications were reported in RCT design studies [24, 27–29]. It seems that this education Is more effective in adults than adults. Although, this study pooled the outcomes of adults and adultescents and showed that HbA1c was reduced in both groups.

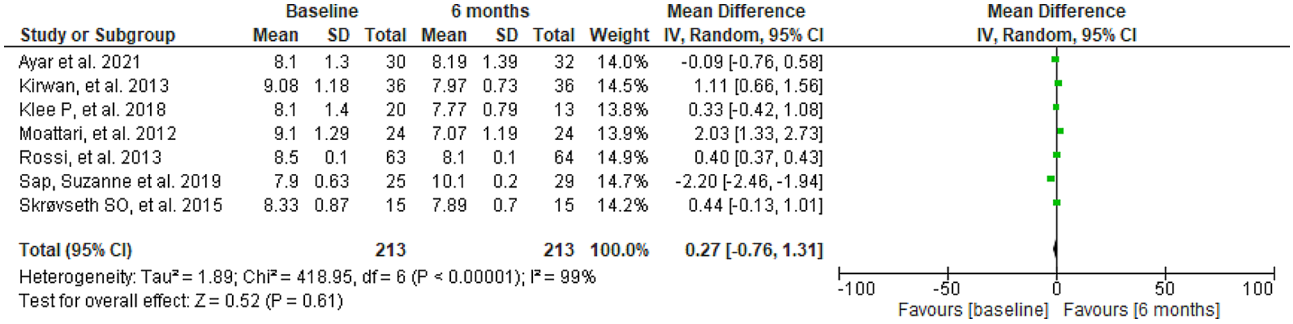

Fig. 5 Overall 6 months HbA1c

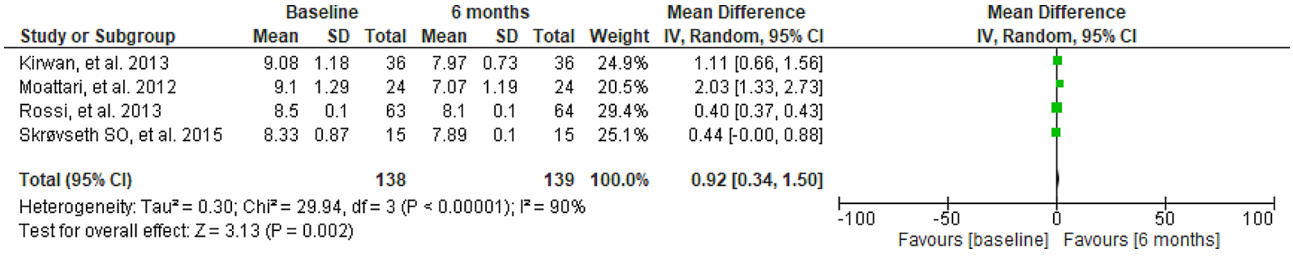

Fig. 6 Overall 6 months HbA1c among adults

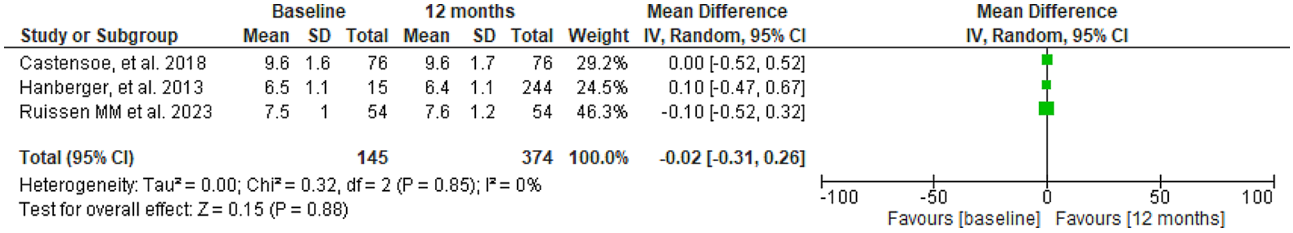

Fig. 7 Overall 12 months HbA1c among adults

A nonenzymatic reaction between glucose and hemoglobin leads to the formation of HbA1c in the mechanism between glycated haemoglobin and T1DM [32]. The average blood glucose level over approximately 120 days is reflected in the HbA1c level in the blood, which is influenced by both physiological and genetic factors [33]. HbA1c is a haemoglobin form that has been chemically linked to certain sugars. It is a nonenzymatic process of glycation of haemoglobin where glucose interacts with the N-terminal end of the beta-globin chain of hemoglobin [34]. During the restructuring, the Schiff base is converted into Amadori products, the most widely known of which is HbA1c. Aldimine is gradually converted into a stable ketoamine form during the secondary step, which is irreversible. β-Val-1, β-Lys-66, and α-Lys-61 are the main sites of hemoglobin glycosylation [35, 36]. HbA1c levels in the blood are indicative of the average blood glucose levels in red blood cells over a period of approximately 120 days in patients with T1DM [37]. This is because the formation of HbA1c occurs in a direct correlation with blood glucose concentrations. Consequently, the amount of glycated haemoglobin in plasma increases with increasing mean plasma glucose [38]. Increased levels of HbA1c have been associated with physiological changes, such as increased blood viscosity which impaired nitric oxide-related relaxation of human mesenteric arteries, therefore promoting hypoxemia and its related systemic vascular vasodilatory changes and responses [39, 40]. The level of HbA1c in individuals with T1DM is also influenced by genetic factors which some genes such as glucokinase (GCK), and melatonin receptor 1B (MTNR1B) influence HbA1c [41]. Moreover, HbA1c levels can be influenced by factors such as hemoglobinopathies, changes in glucose metabolism within the erythrocytes or defects of glucose transport to erythrocyte cells [42].

The DSME is a process of informing people with diabetes about self-care strategies to optimize metabolic control, prevent complications, and improve their quality of life [10]. These studies show that the use of DSME online applications could improve outcomes in individuals with T1DM. This affordable task is crucial because research has shown that individuals with T1DM who reduce their HbA1c level by 1% are less likely to experience heart

Table 1 Characteristics of included studies

Author/ID	Study Design	Application type	Duration/Follow-up	Population	Risk of Bias (Low/Unclear/High)
Ruissen MM et al. 2023, the Netherlands [25]	RCT	POWER2DM	12 months	108 Adults (Intervention group ($n=54$) Control group ($n=54$)(	Low
Ayar et al. 2021, Turkey [27]	RCT	Web-based	6 months	62 Adolescents)Intervention group ($n=30$) Control group ($n=32$)(	Low
Sap, Suzanne et al. 2019, Cameroon [31]	Non-RCT	Social network	2 months	54 Adolescents)Intervention group ($n=25$) Control group ($n=29$)(	Low
Castensoe, et al. 2018, Denmark [28]	Open, parallel RCT	mHealth app	12 months	151 Adolescents)Intervention group ($n=76$) Control group ($n=75$)(	Unclear
Klee P, et al. 2018, Switzerland [30]	RCT	mHealth app	2 weeks	33 Adolescents)Intervention group ($n=20$) Control group ($n=13$)(	Low
Skrøvseth SO, et al. 2015, Norway [26]	RCT	Diabetes Diary	6 months	30 Adults)Intervention group ($n=15$) Control group ($n=15$)(	Low
Hanberger, et al. 2013 Sweden [29]	Blind, Parallel RCT	Web 2.0 Portal	12 months	474 Adolescents)Intervention group ($n=244$) Control group ($n=230$)(	High
Kirwan, et al. 2013, Australia [22]	Two-arm (usual care and intervention) RCT	Glucose Buddy app	9 months	72 Adults)Intervention group ($n=36$) Control group ($n=36$)(	High
Moattari, et al. 2012, Iran [23]	RCT	Specially designed electronic education program	3 months	48 Adults)Intervention group ($n=24$) Control group ($n=24$)(	Low
Rossi, et al. 2013, Italy [24]	Open-label, multicenter, RCT (1:1), parallel-group	Diabetes Interactive Diary	6 months	127 Adults)Intervention group ($n=63$) Control group ($n=64$)(	Unclear

failure, cataracts, amputation, or death [43]. Thus, reducing the complications and risk factors is important for these patients, and maintaining HbA1c at the appropriate level is important for the healthcare system.

This systematic review and meta-analysis has several limitations. Firstly, the included studies had varying durations of follow-up, ranging from 3 to 12 months, which may impact the generalizability of the results. Secondly, the studies used different types of online digital interventions, such as web-based, mobile health applications, or e-health, which may have different effects on glycemic control. Thirdly, the majority of the included patients were adolescents (64.8%), which may limit the applicability of the findings to adult populations. Additionally, the meta-analysis did not assess the long-term sustainability of the effects of online DSME on HbA1c levels beyond 12 months. Furthermore, the review did not explore potential moderators of the effect of online DSME, such as age, duration of diabetes, or baseline HbA1c level. Lastly, the quality of the included studies was not assessed, which may impact the validity of the findings. Future researchers should consider the following improvements for individual studies and Systematic Reviews with Meta-Analysis (SROLs with MA):

Individual Studies:

1. Longer follow-up periods to assess sustained effects of online DSME.
2. More diverse study populations, including older adults and those with comorbidities.
3. Standardized outcome measures and reporting of HbA1c levels.
4. Assessment of potential moderators, such as age, duration of diabetes, and baseline HbA1c level.
5. Exploration of the impact of online DSME on quality of life, diabetes-related distress, and healthcare utilization.

SROLs with MA:

1. Comprehensive searches of gray literature and conference proceedings.

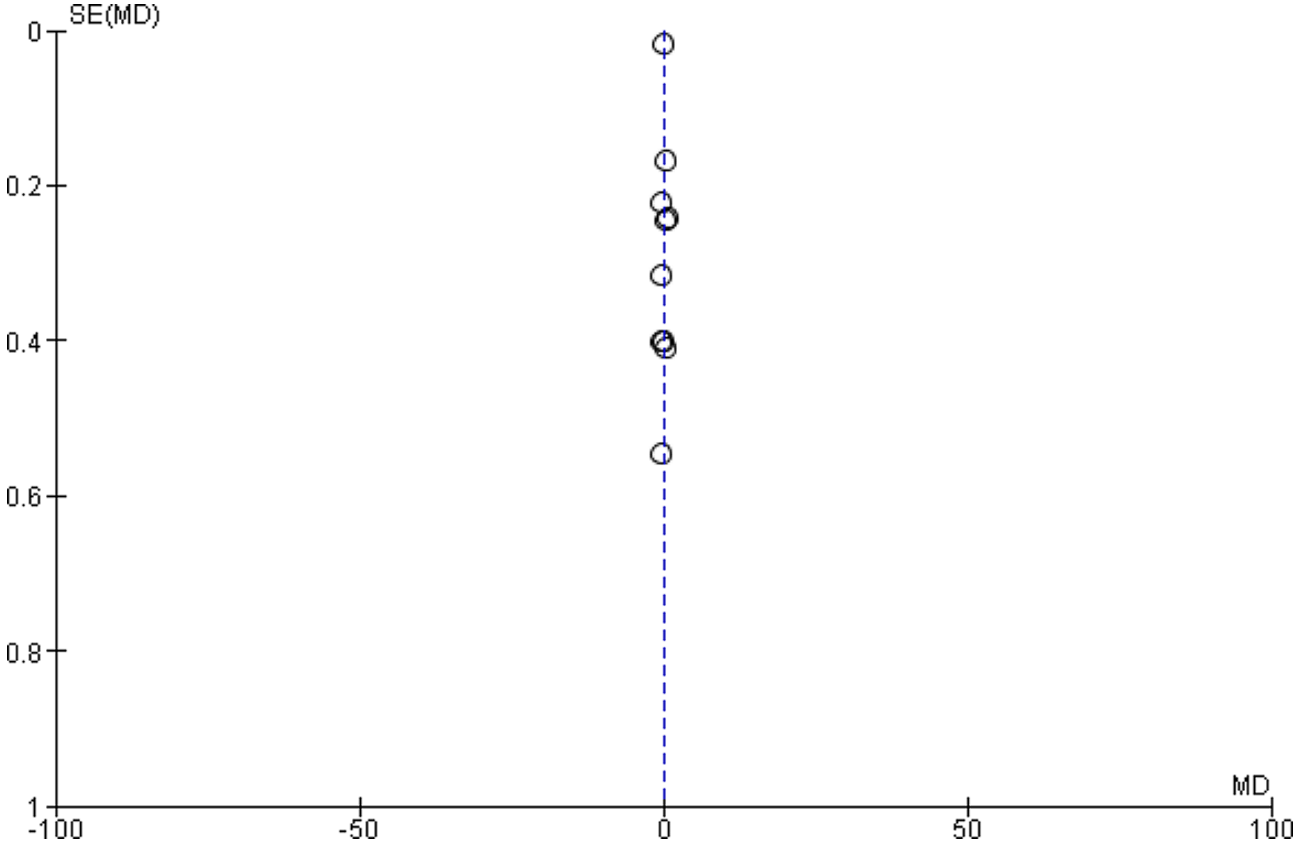

Fig. 8 Funnel plot of comparison

2. Assessment of study quality and risk of bias using standardized tools.
3. Exploration of heterogeneity using subgroup analyses and meta-regression.
4. Consideration of publication bias and small-study effects.
5. Use of more advanced statistical methods, such as network meta-analysis or individual patient data meta-analysis.
6. Inclusion of studies with active comparators (e.g., in-person DSME) to assess relative effectiveness.
7. Assessment of the cost-effectiveness and feasibility of online DSME interventions.
8. Consideration of the impact of online DSME on healthcare disparities and equity.

Conclusion

This meta-analysis provides robust evidence that online DSMES applications are effective in HbA1c levels among patients with T1DM, particularly in adults and adolescents. The findings suggest that online DSMES interventions can lead to significant improvements in glycemic control, with a mean difference in HbA1c levels of 0.27% at 6 months in adolescents and 0.92% in adults. Notably, the effect persisted at 12 months in adults, with a mean difference of -0.02%. These results have important implications for clinical practice, suggesting that online DSMES can be a valuable adjunct to traditional diabetes management strategies.

Abbreviations

IDDM	Insulin-dependent diabetes mellitus
T1DM	Type 1 diabetes mellitus
DSMES	Diabetes self-management education and support
GCK	Glucokinase
MTNR1B	Melatonin receptor 1B

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S.U, M.M.F, F.D, and A.A: contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors read and approved the final manuscript.

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Data availability
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Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
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Competing interests
The authors declare that they have no competing interests.

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