



Research Article

Effect of Digital Health Interventions in Diabetic Distress Among Type-2 Diabetes Mellitus Patients: A Systematic Review and Meta-Analysis

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Abstract: Background: Diabetes distress is a common psychological burden among individuals with type 2 diabetes mellitus (T2DM) and adversely affects self-management, treatment adherence, and health outcomes. Digital health interventions have emerged as promising tools to support diabetes care; however, their effectiveness in reducing diabetes distress remains uncertain. **Purpose:** To evaluate the effectiveness of digital health interventions in reducing diabetes distress among adults with T2DM. **Methods:** A systematic review and meta-analysis of randomised controlled trials (RCTs) was conducted following PRISMA guidelines and registered in PROSPERO (CRD42025115598). PubMed/MEDLINE, Scopus, and Embase were searched from 2010 to September 2025. Studies evaluating digital health interventions, including mobile health applications, telemedicine, web-based platforms, SMS-based programs, and digital behavioral support tools, were included. Pooled mean differences (MDs) and 95% confidence intervals (CIs) were calculated using a random-effects model. **Results:** Twelve RCTs involving 3,147 participants were included. The pooled analysis showed no statistically significant reduction in diabetes distress among participants receiving digital health interventions compared with controls (MD = 0.34, 95% CI: -0.37 to 1.04; p = 0.35). Considerable heterogeneity was observed ($I^2 = 98\%$). Subgroup analyses based on the Diabetes Distress Scale (DDS) and Problem Areas in Diabetes (PAID) scale also demonstrated non-significant effects. The certainty of evidence was rated as moderate. Funnel plot assessment and Egger's regression test (p = 0.128) indicated no significant publication bias. **Conclusion:** Digital health interventions did not demonstrate a significant overall effect on diabetes distress among adults with T2DM. Although some individual studies reported beneficial outcomes, substantial heterogeneity limits definitive conclusions. Further high-quality, adequately powered RCTs are required to identify effective digital strategies for reducing diabetes-related distress.

Keywords: Type 2 Diabetes Mellitus, Diabetes Distress, Digital Health, Mhealth, Telemedicine, Systematic Review, Meta-Analysis

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INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a major global public health concern, with its prevalence continuing to rise worldwide. According to the International Diabetes Federation, approximately 537 million adults were living with diabetes in 2021, and this number is projected to increase substantially in the coming decades [1]. In addition to its well-known metabolic and vascular complications, T2DM is associated with significant psychological burdens that adversely affect disease management and outcomes.

Among these, diabetes distress has emerged as a critical construct, defined as the emotional and psychological burdens associated with living with diabetes and the demands of its self-management [2]. It is distinct from clinical depression, although overlap may occur, and has been shown to negatively influence glycaemic control, treatment adherence, and quality of life [3-4]. The prevalence of diabetes distress among individuals with T2DM is considerable, with studies indicating that up to 36% of patients experience elevated levels of distress [5]. Standardized tools such as

the Diabetes Distress Scale (DDS) and the Problem Areas in Diabetes (PAID) scale are widely used to assess this condition in both clinical and research settings [6-7].

In recent years, digital health interventions have gained increasing attention as innovative approaches to support diabetes management. These interventions—including mobile health (mHealth) applications, telemedicine, web-based platforms, and remote monitoring systems—offer scalable and cost-effective solutions to deliver education, behavioral support, and continuous monitoring [8]. Evidence suggests that digital interventions can improve glycaemic outcomes and self-management behaviours in patients with T2DM [9-10]. Additionally, by enhancing patient engagement, self-efficacy, and access to care, these interventions may help alleviate the psychological burden associated with diabetes [11].

Despite growing interest in this area, the evidence regarding the effectiveness of digital health interventions in reducing diabetes distress remains inconsistent. Variations in intervention design, duration, patient populations, and outcome measurement tools have contributed to heterogeneous findings across studies. Furthermore, it is unclear whether the impact of digital interventions differs depending on the instrument used to measure distress, such as DDS or PAID.

Therefore, the present systematic review and meta-analysis aims to evaluate the effect of digital health interventions on diabetes distress among adults with type 2 diabetes mellitus, with a specific focus on differences in outcomes measured using DDS and PAID scales. By synthesizing evidence from randomized controlled trials, this study seeks to provide a clearer understanding of the role of digital interventions in addressing the psychological dimensions of diabetes care.

MATERIALS AND METHODS

The Cochrane Handbook for Systematic Reviews of Interventions was followed to conduct the present systematic review and meta-analysis [12]. This systematic review and meta-analysis were conducted and reported following the suggestions of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [13]. The protocol was registered in PROSPERO (registration number: CRD42025115598).

Search S Strategy

A systematic search was performed in three databases: MEDLINE (through PubMed), Scopus, and Embase 2010 onwards to September 2025, corresponding to the period of rapid growth in digital health technologies. The search aimed to identify all eligible studies assessing the effects of digital interventions on diabetes distress in patients with T2D. Our search strategy was according to the PICO approach and included the following free and controlled (MeSH) terms: (("diabetes distress" OR "diabetes-related distress" OR "emotional distress" OR "psychological distress") AND ("digital health" OR "digital intervention" OR "Digital Health Technology" OR "mHealth" OR "eHealth" OR "telemedicine" OR "mobile application" OR "internet-based intervention" OR "Wearable Electronic Devices" OR "text messaging") AND ("type 2 diabetes" OR "diabetes mellitus type2" OR Diabetes Mellitus, Type II)). The complete search strategy adapted for this study is available in Supplementary TableS1.

Study Selection

The titles and abstracts of the retrieved studies were independently examined by two co-authors. For those studies in which titles and abstracts were related to the purpose of our review, we screened them against eligibility criteria. The inclusion criteria were as follows:

- **Type of study:** RCTs reporting the effect of an eligible intervention on diabetes-related distress (either as a primary or secondary endpoint), irrespective of duration, type or type of randomization
- **Type of participants:** individuals aged more than 18 years diagnosed with T2D experiencing diabetes-related distress
- **Type of intervention:** focused on digital health interventions such as mobile health (mHealth) applications, web-based platforms, SMS-based programs, teleconsultations, and digital behavioural support tools designed to reduce diabetes related distress
- **Comparison:** control group included T2D patients with distress receiving usual care or an active comparator (another intervention known or expected to reduce diabetes related distress)
- **Outcomes:** changes in diabetes distress based on scales such as the Diabetes Distress Screening(DDS), the Problems Area In Diabetes (PAID)

We excluded letters, unpublished results, and conference or meeting abstracts. We also excluded studies that included populations with type 1 diabetes. Finally, a third co-author was consulted in case of disagreements between the initial reviewers.

Table 1: Characteristics of Included Studies Evaluating Digital and Telehealth Interventions for Diabetes-Related Distress

Author; Year	Country	Sample	Treatment (n)	Control (n)	Mean Age (Years; SD)	Intervention	Control	Time Period	Outcomes Included
Crowley MJ [19]	US	T2DM	101	99	57.8 (8.2)	Comprehensive Telehealth intervention	Telemonitoring	12 months	DDS
Bretschneider [20]	Germany	T2DM	73	76	60.6 (10.8)	Vitadio mobile app	Standard, usual diabetic care	6 months	PAID
Presley [21]	US	T2DM	62	35	54.9 (8.3)	DSME plus peer support by CHWs using the mHealth app	DSME alone	6 months	DDS
Mitchell [22]	US	T2DM	158	151	55.4 (10.6)	Virtual world DMGVs	In-person DMGVs	6 months	DDS
Dobson [23]	New Zealand	T2DM	183	183	58.1 (10.6)	SMS4BG(automated self-management support program delivered by SMS)	Standard diabetic care	9 months	DDS
Bendig E [24]	Germany	T2DM	21	21	46.9 (14.4)	ACT on Diabetes(guided internet intervention delivered on the online platform Minddistrict)	Waitlist	8 weeks	PAID
Bladwin PA [25]	Australia	T2DM	391	379	58 (10.6)	My Compass (fully automated eMH program that contains 12 interactive modules and allows for self-monitoring of 20 cognitive behavioural variables. Also provides SMS/email reminders, mental health care tips, motivational messages)	Healthy lifestyle	12 months	DDS
Trief [26]	New York	T2DM	97	78	56.8 (10.9)	Telephone session, 75 minutes duration on comprehensive diabetes education	waiting list	12 months	DDS
Roth [27]	Germany	T2DM	104	100	55.2 (13.7)	ESYSTA(digital application to support people with diabetes for disease management + German standard of care for diabetes)	German standard of care for diabetes	6 months	PAID
Hilmarsdottir [28]	Iceland	T2DM	18	19	50.9 (11.8)	Lifestyle supporting smartphone application(SidekickHealth) + standard care	Standard care for diabetes	6 months	PAID
Nobis [10]	Germany	T2DM	129	127	51 (12)	GET ON M.E.D(minimally guided web-based self-help intervention for diabetes patients)	Psychoeducation	12 months	PAID
Yu [19]	Canada	T2DM	102	111	55.1 (13.6)	My Diabetes Plan (web-based PtDA)	Diabetes Canada patient pamphlet	12 months	DDS

Data Extraction and Quality Assessment

Two co-authors independently conducted the data extraction and quality assessment of the included studies. In cases of disagreement, a third co-author was consulted to resolve the issue. The following information was extracted from the included studies: first author and publication year, country, study design, population characteristics, sample size in each group, intervention type, comparison group, outcomes of interest and the scale used to measure them, duration of the intervention and the main finding.

The Cochrane's Risk-of-Bias 2 (RoB-2) tool was used to assess the quality of the included randomized controlled trials (RCTs) [14]. The risk of bias was assessed across five domains:

- Randomization process
- Deviations from intended interventions
- Missing outcome data
- Measurement of outcomes
- Selection of the reported results

Each domain was rated as "low risk of bias," "some concerns," or "high risk of bias." Based on these assessments, the overall risk of bias for each study was classified as "low risk of bias," "some concerns," or "high risk of bias."

Grading the Quality of Evidence

The certainty of evidence in the present systematic review was evaluated using the GRADE Working Group (Grades of Recommendations, Assessment, Development, and Evaluation) approach [15]. The outcome of diabetes distress was assessed for certainty of evidence and classified as high, moderate, low, or very low quality based on study design, risk of bias, inconsistency, indirectness, imprecision, and publication bias

Data Synthesis

A meta-analysis was performed using studies that reported sufficient data. Pre- and post-intervention means, standard deviations (SDs), and sample sizes were extracted for each trial arm. For studies that did not provide these values, the mean difference (MD) along with the standard error or SD of the change scores was obtained. Subsequently, standardized mean differences (SMDs) with corresponding 95% confidence intervals (CIs) were calculated for each study using the DerSimonian and Laird random-effects model [16].

Data Analysis

Analyses were performed using Review Manager Version 5 [17]. Outcomes at the endpoint and follow-up were meta-analyzed when at least three studies provided the necessary data. SMD with 95% CI was calculated. Heterogeneity was assessed using I^2 , with values greater than 50% indicating heterogeneity. As such, outcomes were assessed using a random effect model when $I^2 > 50\%$, while the fixed effect model was used when studies showed $I^2 < 50\%$. Odds Ratio (OR) with 95% CI was calculated to assess intervention acceptability based on drop-out rates. Publication bias was assessed by visually inspecting the funnel plot and through the Egger's regression test [18]. Sub-group analyses were performed based on DDS vs. PAID.

RESULTS

A total of 13 randomized controlled trials (RCTs) evaluating the effect of digital health interventions on diabetes distress among adults with type 2 diabetes mellitus (T2DM) were included in the review. The studies were published between 2015 and 2025 and were conducted across seven countries, namely the United States ($n = 4$), Germany ($n = 4$), Canada ($n = 1$), Iceland ($n = 1$), Australia ($n = 1$), and New Zealand ($n = 1$), providing broad geographical representation.

Overall, the included studies enrolled 3,147 participants, of whom 1,439 were allocated to intervention groups and 1,379 to control groups. Sample sizes varied substantially, ranging from 37 participants in the study by Hilmarsdóttir *et al.* [28] to 770 participants in the trial conducted by Baldwin *et al.* [25]

The mean age of participants ranged from 46.9 to 60.6 years, indicating that the interventions were predominantly evaluated among middle-aged and older adults with T2DM. Among studies reporting age data, the weighted mean age was approximately 56.2 years.

A wide range of digital health interventions was investigated. These included telehealth-based care, mobile health (mHealth) applications, smartphone applications, web-based self-management programs, internet-delivered psychological interventions, SMS-based self-management support systems, virtual diabetes group visits, patient decision aids, and telephone-based educational interventions. Several interventions incorporated behavioural change techniques, self-monitoring components, peer support, cognitive behavioural therapy principles, automated reminders, motivational messaging, and remote communication with healthcare providers. Control groups generally received standard diabetes care, usual clinical management, psychoeducation, healthy lifestyle information, wait-list control, printed educational materials, or face-to-face diabetes education.

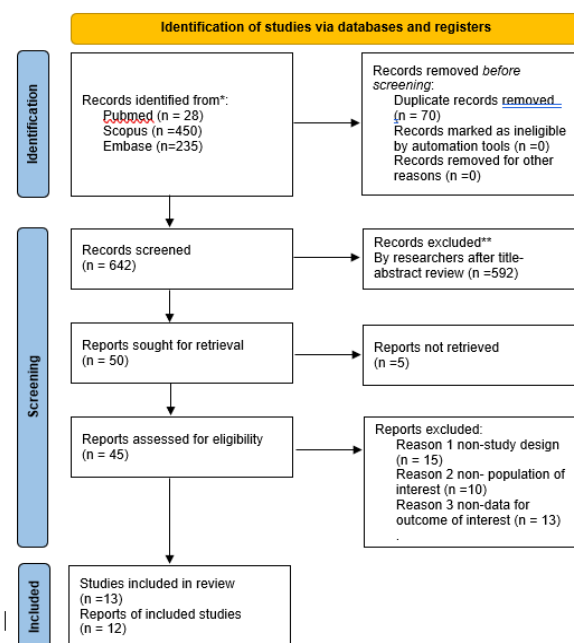
The duration of interventions ranged from 8 weeks to 12 months. One study had a follow-up period of 8 weeks, while the majority of studies evaluated outcomes over 6 to 12 months. Six studies reported a follow-up duration of 12 months, five studies assessed outcomes at 6 months, and one study evaluated participants after 9 months.

Diabetes distress was measured using validated instruments, primarily the Diabetes Distress Scale (DDS) and the Problem Areas in Diabetes (PAID) scale. Seven studies utilized the DDS as the outcome measure, whereas five studies assessed diabetes distress using the PAID scale.

Regarding intervention modality, app-based and smartphone-delivered interventions were the most common ($n = 6$), followed by web-based interventions ($n = 3$), telehealth programs ($n = 1$), SMS-based interventions ($n = 1$), and telephone-based educational interventions ($n = 1$). This diversity reflects the expanding use of digital technologies to address psychological and emotional challenges associated with diabetes self-management. Detailed characteristics of the included studies are presented in Table 1.

The pooled analysis of 12 studies evaluating the effect of digital interventions on diabetes distress among patients with type 2 diabetes mellitus showed no statistically significant overall effect compared with the control group (MD = 0.34, 95% CI: -0.37 to 1.04; $Z = 0.93$, $p = 0.35$). Considerable heterogeneity was observed across the included studies ($\text{Tau}^2 = 1.05$; $\text{Chi}^2 = 608.54$, $\text{df} = 11$, $p < 0.00001$; $I^2 = 98\%$), and therefore a random-effects model was applied.

PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).

**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

Fig.1.Flowdiagram of the studies (PRISMA). PRISMA, PreferredReportingItemsforSystematicReviewsandMeta-Analyses2020.

Figure 1: PRISMA 2020 Flow Diagram of the Study Selection Process for the Systematic Review

Among the included studies, some demonstrated a significant reduction in diabetes distress, favoring the digital intervention group, including the studies by Baldwin *et al.*, Crowley *et al.*, and Nobis *et al.* [19,25,27], whereas others either favored the control group or showed no significant difference between groups. Studies such as Bendig *et al.*, Roth *et al.* and Trief *et al.* [24,26-27]. demonstrated wide confidence intervals, indicating substantial variability and possible imprecision in effect estimates.

Overall, despite several individual studies reporting beneficial effects of digital interventions, the pooled evidence did not demonstrate a statistically significant improvement in diabetes distress among individuals with type 2 diabetes. The substantial heterogeneity suggests marked differences in intervention characteristics, study populations, outcome assessment methods, and duration of follow-up across studies.

Subgroup analysis was performed based on the diabetes distress assessment tool used, namely the Diabetes Distress Scale (DDS) and the Problem Areas in Diabetes (PAID) scale.

In the DDS subgroup, seven studies involving 1,094 participants were included. The pooled analysis demonstrated a trend toward reduction in diabetes distress favoring digital interventions; however, the overall effect was not statistically significant (MD = 0.71, 95% CI: -0.05 to 1.47; Z = 1.83, p = 0.07). Considerable heterogeneity was observed among the included studies (Tau² = 1.02; Chi² = 582.08, df = 6, p < 0.00001; I² = 99%). Among the DDS-based studies,

Baldwin *et al.* and Crowley *et al.* [19,25] showed significant reductions in diabetes distress favoring the intervention group, whereas Trief *et al.* [26] demonstrated results favoring the control group (Figure 1).

In the PAID scale subgroup, five studies with 345 participants were analyzed. The pooled estimate showed no statistically significant effect of digital interventions on diabetes distress compared with controls (MD = -1.39, 95% CI: -4.14 to 1.37; Z = 0.99, p = 0.32). Moderate heterogeneity was identified within this subgroup (Tau² = 4.47; Chi² = 8.61, df = 4, p = 0.07; I² = 54%). Among the included studies, Nobis *et al.* [10] reported a significant reduction in diabetes distress favoring digital interventions, while the remaining studies showed non-significant findings.

The test for subgroup differences was not statistically significant (Chi² = 2.07, df = 1, p = 0.15; I² = 51.7%), indicating that the type of diabetes distress assessment scale used did not significantly influence the overall effect estimate.

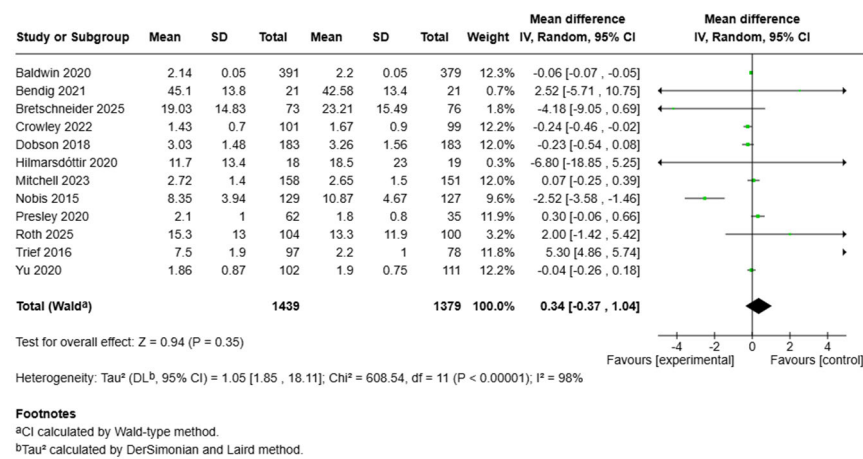


Figure 2: Forest Plot of the Meta-Analysis of the Effects of Digital and Telehealth Interventions on Diabetes-Related Distress

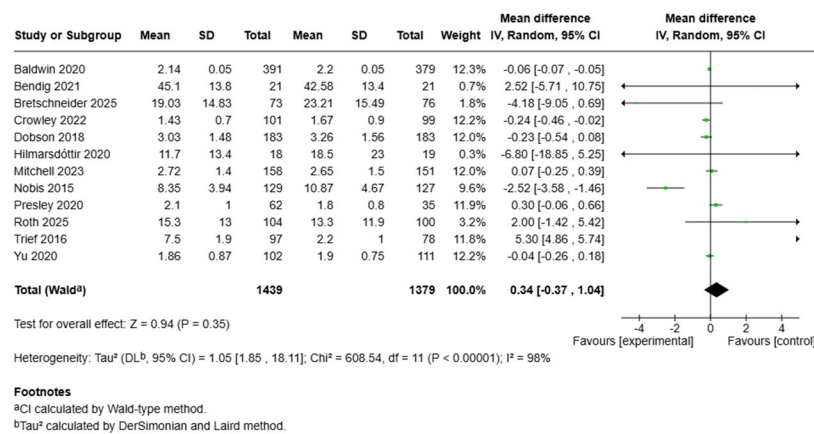


Figure 3: Forest Plot of the Meta-Analysis of the Effects of Digital and Telehealth Interventions on Diabetes-Related Distress

Risk of Bias Assessment

The methodological quality of the included studies was evaluated using the Cochrane Risk of Bias tool across five domains: randomization process, deviations from intended interventions, missing outcome data, measurement of outcomes, and selection of reported results. Overall, the majority of studies were judged to have a low risk of bias or some concerns across the assessed domains (Figure 2-3).

Most studies demonstrated low risk of bias in the domains related to the randomization process and outcome measurement, indicating adequate methodological rigor in sequence generation and outcome assessment. However, some concerns were identified primarily in the domains of deviations from intended interventions and missing outcome data, mainly due to inadequate reporting of blinding procedures, attrition, and adherence to interventions.

A small proportion of studies were classified as having a high risk of bias, predominantly owing to incomplete outcome data and potential selective reporting of outcomes. Despite these limitations, the overall methodological quality of the included studies was considered moderate, supporting the validity of the pooled estimates.

The quality of evidence for the included outcome was assessed using the GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach. Evidence from the included studies was evaluated across the domains of risk of bias, inconsistency, indirectness, imprecision, and publication bias. Based on these criteria, the certainty of evidence was rated as high, moderate, low, or very low. The overall quality of evidence for diabetes distress was found to be moderate, indicating that further research may have an important impact on the confidence in the estimated effect and may change the estimate.

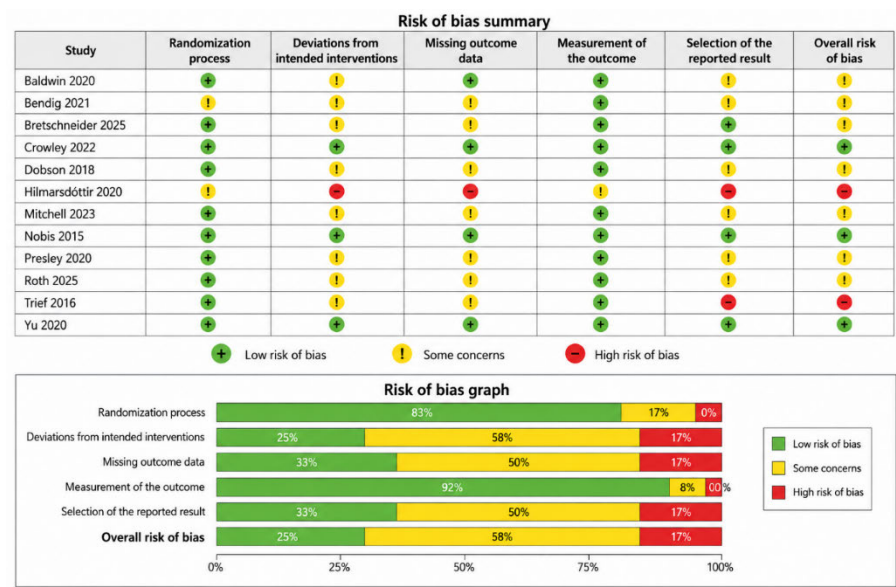


Figure 4: Risk of Bias Assessment of Included Studies

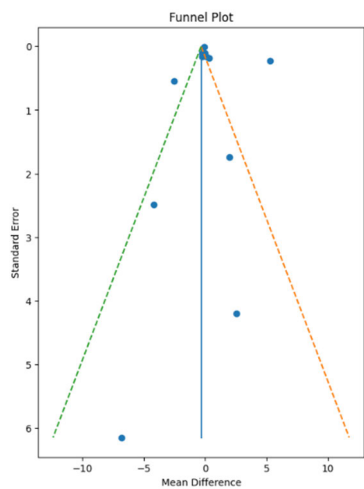


Figure 5: Funnel Plot

Publication Bias

Publication bias was assessed for all considered outcomes as shown in Figure 5. Visual inspection of the funnel plot shows no marked asymmetry. The distribution of studies around the pooled effect estimate appears reasonably balanced, suggesting the absence of substantial publication bias or small-study effects. Egger's regression test was also performed it was not statistically significant ($p = 0.128$), indicating no evidence of significant funnel plot asymmetry.

DISCUSSION

This systematic review and meta-analysis synthesized evidence from 12 studies evaluating the effectiveness of digital interventions in reducing diabetes distress among individuals with type 2 diabetes mellitus. The pooled analysis demonstrated no statistically significant overall effect of digital interventions compared with control conditions (MD = 0.34, 95% CI: -0.37 to 1.04, $p = 0.35$). Although several individual studies reported favorable outcomes, the combined evidence did not support a significant reduction in diabetes distress. Furthermore, substantial heterogeneity was observed across the included studies ($I^2 = 98\%$), indicating considerable variability in intervention effects and limiting the certainty of the pooled estimate.

These findings are consistent with previous systematic reviews demonstrating that digital interventions improve glycaemic control and diabetes self-management more consistently than psychosocial outcomes. Hou *et al.* reported significant improvements in HbA1c with mobile health interventions [9], whereas Greenwood *et al.* concluded that

technology-enabled diabetes self-management education improved self-care behaviours but produced variable psychological benefits [11]. Likewise, the Cochrane review by Pal *et al.* found modest benefits for self-management but inconsistent effects on emotional outcomes [30]. The current findings also align with conceptual work by Polonsky *et al.* and Fisher *et al.*, who demonstrated that diabetes distress is distinct from depression and requires targeted psychosocial support [2,7]. This may explain why interventions primarily designed to improve diabetes self-management do not consistently reduce diabetes distress. Among the included trials, Baldwin *et al.*, Crowley *et al.*, and Nobis *et al.* reported significant improvements [10,19,25]. Their interventions incorporated behavioural coaching, personalised feedback, self-monitoring, and regular interaction with healthcare professionals. Similar benefits have been reported by van Bastelaar *et al.* using web-based cognitive behavioural therapy [31] and by Kempf *et al.* using structured digital lifestyle coaching [32], suggesting that psychological support embedded within digital platforms may enhance effectiveness. The high heterogeneity observed in this review is likely attributable to differences in intervention design, intensity, follow-up duration, participant engagement, and digital literacy. Eysenbach's 'law of attrition' provides a theoretical explanation for declining engagement with digital interventions over time, which may reduce long-term effectiveness. Subgroup analyses based on DDS and PAID showed no statistically significant subgroup differences. However, DDS-based studies showed a trend towards benefit, possibly because DDS is more responsive to diabetes-specific behavioural changes than PAID.

This review has several strengths. A comprehensive search strategy was employed, and quantitative synthesis was performed using rigorous meta-analytic methods. Inclusion of controlled studies strengthened the reliability of the findings. Additionally, subgroup analyses based on diabetes distress measurement tools provided valuable insights into potential sources of heterogeneity.

However, several limitations should be acknowledged. First, the substantial heterogeneity observed across studies limits the interpretability of pooled estimates. Second, intervention characteristics differed considerably, preventing direct comparison between digital approaches. Third, several studies had relatively small sample sizes and short follow-up durations, which may have reduced statistical power to detect significant differences. Finally, the use of different diabetes distress measurement instruments may have introduced additional variability.

Future research should focus on identifying the components of digital interventions that are most effective in reducing diabetes distress. Standardization of intervention characteristics and outcome measures would improve comparability across studies. Large multicenter randomized controlled trials with longer follow-up periods are needed to determine whether digital interventions can produce sustained improvements in psychological outcomes. Furthermore, future investigations should explore factors influencing intervention adherence and engagement, as these may represent critical determinants of effectiveness.

In conclusion, the findings of this meta-analysis suggest that digital interventions do not significantly reduce diabetes distress among individuals with type 2 diabetes mellitus when compared with usual care or control interventions. Although several individual studies reported beneficial effects, the pooled evidence remained non-significant and was characterized by substantial heterogeneity. Further high-quality research is required to identify the most effective digital strategies for addressing diabetes-related emotional distress and to establish their long-term clinical value.

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Conflicts of Interest

The authors declare no conflict of interest.

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