Effectiveness of Digital Health Intervention Strategies on Type 2 Diabetes Management□A Systematic Review and Network Meta-Analysis

Min Li, Shiyu Liu, Binyang Yu, Ning Li, Haiyan Yang, Haiyan He, Na Zhang, Jingru Ma, Meichen Sun, Hong Du, Rui Gao

Submitted to: Journal of Medical Internet Research
on: June 12, 2024

Table of Contents

Effectiveness of Digital Health Intervention Strategies on Type 2 Diabetes Management?A Systematic Review and Network Meta-Analysis

Min Li[1]; Shiyu Liu[2]; Binyang Yu[3]; Ning Li[1]; Haiyan Yang[1]; Haiyan He[1]; Na Zhang[1]; Jingru Ma[2]; Meichen Sun[2]; Hong Du[2]; Rui Gao[1]

[1]School of Nursing Health Science Center Xi 'an Jiaotong University Xi 'an CN
[2]School of Public Health Xi'an Jiaotong University Xi 'an CN
[3]Graduate School Beijing University of Chinese Medicine Beijing CN

Corresponding Author:
Rui Gao
School of Nursing
Health Science Center
Xi 'an Jiaotong University
Department of Nursing, Xi 'an Jiaotong University Medical Science Center, 74 Yanta West Road, Xi 'an 710061, China
Xi 'an
CN

Abstract

Background: Various mobile technologies and digital health interventions (DHIs) have been developed for type 2 diabetes management. Strategies are crucial for the effectiveness of DHIs. However, there is currently a lack of categorization and summary of the strategies used in DHIs of type 2 diabetes mellitus (T2DM).

Objective: This study aims to (1) identify and categorize the strategies used in DHIs on type 2 diabetes management; (2) assess the effectiveness of these DHI strategies; (3) compare and rank the efficacy of different strategy combinations on glycated hemoglobin A1c (HbA1c), fasting blood glucose (FBG), body mass index (BMI), and weight loss.

Methods: Relevant randomized controlled trials (RCTs) were extracted from PubMed, Web of Science, and Scopus databases. Three rounds of screening and selection were conducted. The strategies were identified and categorized based on the principles of Behavior Change Techniques (BCTs) and Behavior Strategies (BSs). The synthesis framework for the assessment of health information technology (SF/HIT) was used to structure the evaluation of the DHI strategies qualitatively. A network meta-analysis was performed to compare the efficacy of different strategy combinations. The data quality was assessed using the Cochrane Risk of Bias tool. This study was registered in PROSPERO, number CRD42024544629.

Results: A total of 52 RCTs were included, identifying 63 strategies categorized into 19 strategy themes. The most commonly used strategies were guide, monitor, management, and engagement. Most studies reported positive or mixed outcomes for most indicators based on the SF/HIT. Research involving a medium or high quantity of strategies was found to be more effective than research involving a low quantity of strategies. 27 RCTs were included in the network-meta analysis. The strategy combination composed of communication, engagement, guide, and management was most effective in reducing HbA1c, while the strategy combination that included guide, management, and monitor was effective in reducing FBG. Strategy combination composed of communication, engagement, goal setting, management, and support was most effective for BMI and weight management.

Conclusions: Several DHI strategy combinations have been effective in reducing HbA1c, FBG, BMI, and weight loss in type 2 diabetes management. Healthcare professionals should be encouraged to apply these promising strategy combinations in DHIs during clinical care. Future research should further explore and optimize the design and implementation of strategies.

(JMIR Preprints 12/06/2024:63209)
DOI: https://doi.org/10.2196/preprints.63209

Preprint Settings

1) Would you like to publish your submitted manuscript as preprint?
✓ **Please make my preprint PDF available to anyone at any time (recommended).**

Please make my preprint PDF available only to logged-in users; I understand that my title and abstract will remain visible to all users.
Only make the preprint title and abstract visible.
No, I do not wish to publish my submitted manuscript as a preprint.

2) If accepted for publication in a JMIR journal, would you like the PDF to be visible to the public?

✔ **Yes, please make my accepted manuscript PDF available to anyone at any time (Recommended).**
Yes, but please make my accepted manuscript PDF available only to logged-in users; I understand that the title and abstract will remain v
Yes, but only make the title and abstract visible (see Important note, above). I understand that if I later pay to participate in <a href="http

Original Manuscript

Title page

Effectiveness of Digital Health Intervention Strategies on Type 2 Diabetes Management：A Systematic Review and Network Meta-Analysis

Min Li[1], Shiyu Liu[2], Binyang Yu[3], Ning Li[1], Haiyan Yang[1], Haiyan He[1], Na Zhang[1], Jingru Ma[2], Meichen Sun[2], Hong Du[2], Rui Gao[1#]

[1]School of Nursing, Xi 'an Jiaotong University Health Science Center, Xi 'an 710061, China;
[2]School of Public Health, Xi'an Jiaotong University, Xi'an ,710061, China;
[3]Graduate School, Beijing University of Chinese Medicine/ Xiyuan Hospital, Chinese Academy of Chinese Medical Sciences, Beijing 100029, China

[#]Corresponding author
Rui Gao, PhD
School of Nursing
Xi 'an Jiaotong University Health Science Center
Department of Nursing, Xi 'an Jiaotong University Medical Science Center, 74 Yanta West Road, Xi 'an 710061, China
Email: gaorui@xjtu.edu.cn

Effectiveness of Digital Health Intervention Strategies on Type 2 Diabetes Management：A Systematic Review and Network Meta-Analysis

Abstract

Background: Various mobile technologies and digital health interventions (DHIs) have been developed for type 2 diabetes management. Strategies are crucial for the effectiveness of DHIs. However, there is currently a lack of categorization and summary of the strategies used in DHIs of type 2 diabetes mellitus (T2DM).

Objective: This study aims to (1) identify and categorize the strategies used in DHIs on type 2 diabetes management; (2) assess the effectiveness of these DHI strategies; (3) compare and rank the efficacy of different strategy combinations on glycated hemoglobin A1c (HbA1c), fasting blood glucose (FBG), body mass index (BMI), and weight loss.

Methods: Relevant randomized controlled trials (RCTs) were extracted from PubMed, Web of Science, and Scopus databases. Three rounds of screening and selection were conducted. The strategies were identified and categorized based on the principles of Behavior Change Techniques (BCTs) and Behavior Strategies (BSs). The synthesis framework for the assessment of health information technology (SF/HIT) was used to structure the evaluation of the DHI strategies qualitatively. A network meta-analysis was performed to compare the efficacy of different strategy combinations. The data quality was assessed using the Cochrane Risk of Bias tool. This study was registered in PROSPERO, number CRD42024544629.

Results: A total of 52 RCTs were included, identifying 63 strategies categorized into 19 strategy themes. The most commonly used strategies were *guide*, *monitor*, *management*, and *engagement*. Most studies reported positive or mixed outcomes for most indicators based on the SF/HIT. Research involving a medium or high quantity of strategies was found to be more effective than research involving a low quantity of strategies. 27 RCTs were included in the network-meta analysis. The strategy combination composed of *communication, engagement, guide*, and *management* was most effective in reducing HbA1c, while the strategy combination that included *guide, management,* and *monitor* was effective in reducing FBG. Strategy combination composed of *communication*, *engagement*, *goal setting*, *management*, and *support* was most effective for BMI and weight management.

Conclusions: Several DHI strategy combinations have been effective in reducing HbA1c, FBG, BMI, and weight loss in type 2 diabetes management. Healthcare professionals should be encouraged to apply these promising strategy combinations in DHIs during clinical care. Future research should further explore and optimize the design and implementation of strategies.

Keywords: T2DM; digital health interventions; strategy; strategy combinations; effectiveness; network meta-analysis

Introduction

The severity of type 2 diabetes

Type 2 diabetes mellitus (T2DM) has become a serious public health problem worldwide. It is a progressive disease that can impair health-related quality of life (QoL)[1,2], while also imposing

substantial economic burdens on individuals, health systems, and society[3]. By 2040, there will be 642 million diabetes patients worldwide, with the incidence of T2DM on the rise across all regions[4]. T2DM accounts for more than 90% of the diagnosis in all types of diabetes, and it can cause various complications[5]. The goal of diabetes treatment is to prevent or delay complications and optimize QoL[6]. Poor glucose control is associated with the occurrence of complications[7]. Glycated hemoglobin (HbA1c) can be used to determine glucose control level[8]. Continuous monitoring of fasting blood glucose (FBG) can intuitively reflect the patient's glucose changes. Obesity is closely related to T2DM, and weight gain is an independent risk factor for T2DM[9]. Controlling glucose and body weight within the normal range can effectively reduce the complications of diabetes patients[10]. A large number of studies have shown that type 2 diabetes can be slowed down, stopped or even reversed by changing lifestyle (such as low calorie diet and increasing physical activity)[11,12]. This can reduce long-term complications and may extend life expectancy[13].

The effect of digital health interventions (DHIs)

However, maintaining glycemic control is a challenge for both patients and healthcare providers, making it difficult to encourage or motivate patients to make long-term lifestyle changes, explain their self-monitoring of blood glucose data, provide immediate feedback, and understand their lifestyle[14]. Recognizing that patients require more self-management support, various mobile technologies (mobile healthcare) and DHIs have been developed[15–18], including mobile apps, SMS (short message service), wearable and ambient sensors, and social media. These technologies can provide early support for the improvement of diabetes patients' health behaviors, encouraging T2DM patients to eat healthily and take physical exercise, and help to collect personal data and analyze data to assess clinical conditions. The data reported by patients can be used to customize personalized feedback information, including health promotion, motivation, encouragement, reminders, and emotional support information[19,20]. Relevant systematic reviews and meta-analyses have confirmed the effectiveness of DHIs on behavior change, blood glucose control and weight loss of diabetes patients[21–24].

The critical role of strategies in DHIs for type 2 diabetes management

Strategies play a pivotal role in enhancing the efficacy of DHIs for patients with T2DM, with the careful selection and implementation of appropriate strategies being crucial to DHI success[25]. Within the realm of digital interventions, employing suitable strategies, such as user-centered participatory design, can heighten user engagement, thereby rendering intervention measures more appealing and efficacious[26]. Furthermore, mobile technology interventions informed by strategies such as health behavior theory hold the potential for more comprehensive mechanisms of behavior change, fostering a healthcare approach that is both impactful and sustainable[27]. Through the identification and categorization of diverse strategies, researchers and practitioners can gain deeper insights into the effective methodologies and techniques employed in DHIs. This involves assessing the strengths and limitations of various strategies and their applicability to specific health domains or populations[28].

Current findings on DHI strategies for type 2 diabetes management

There have been studies that systematically summarize the strategies used in DHIs currently. For example, various engagement strategies have been reported in DHIs for mental health promotion,

including personalization, human and social support, gamification, personalized feedback, and reminders, which work best to promote engagement[29]. Study indicated that the effectiveness of internet-based interventions correlates with the extensive utilization of theory, particularly the theory of planned behavior, the incorporation of a greater number of behavior change techniques, and the integration of additional methods for interacting with participants[25]. A systematic review and meta-analysis of lifestyle interventions in postpartum women found that the provision of certain strategies including problem-solving, goal-setting of outcome, reviewing outcome goal, feedback, and self-monitoring of behaviour were associated with greater decreases in energy intake[30]. In addition, the report analyzed loneliness reduction strategies including improving social skills, enhancing social support, increasing opportunities for social interaction, and addressing deficits in social cognition[31]. It was suggested in a narrative umbrella review that credible source, social support, prompts and cues, graded tasks, goals and planning, feedback and monitoring, and human coaching and personalization components increased the effectiveness of DHIs targeting the prevention and management of noncommunicable diseases[32]. Moreover, substantial strategies have been found to be effective in improving recruitment, reducing loss to follow-up, and enhancing retention during intervention in some trials[33–36]. However, there is a lack of categorization and summary of the strategies used in DHIs of T2DM at present. Although previous research compared the effectiveness of 5 strategies on type 2 diabetes management, notably its narrow focus on telemedicine in DHIs, as well as a comparison of several single strategies, without systematic summary of the strategies used in DHIs[37]. Meanwhile, the majority of interventional studies incorporate different numbers and combinations of strategies rather than focusing on individual strategies, and it is not yet known which strategy combination has the best effect. Therefore, it is very necessary to summarize and compare strategies and strategy combinations, identify the content of the strategies, and further determine the optimal number and form of strategy combinations to provide more practical guidance for precise and personalized digital health management of T2DM.

Our study objectives

This study aims to (1) identify and categorize the strategies used in DHIs on type 2 diabetes management; (2) assess the effectiveness of these DHI strategies; (3) compare and rank the efficacy of different strategy combinations on HbA1c, FBG, BMI, and weight loss.

Methods

Protocol and registration

This systematic review followed the network meta-analysis extension for the Preferred Reporting Items for Systematic Review and Meta-analysis 2020 statement (PRISMA-NMA) to design and report[38]. The protocol for this study has been registered with PROSPERO (CRD42024544629).

Data sources

We conducted a comprehensive search for published English papers from PubMed, Web of Science, and Scopus. This search employed a combination of digital health and intervention-related terms, along with database-specific subject headings and filters, to ensure thoroughness and focus. The detailed search strategy can be found in the appendix 1. The time span was from 1 January 1999 to 10 March 2024.

Data selection and extraction

All the searched records were imported into EndNote X9 to eliminate duplicate studies. The first round screening and selection focused on identifying DHIs. Our criteria were as following： (1) digital: the means of intervention should be digital, primarily including wearable devices, telemedicine, electronic health records, electronic medical records, mobile phone applications, web pages, blogs, emails, text messages, social media, and similar technologies. (2) health: the intervention must be health-related, encompassing health behavior improvement, disease treatment, and health education, etc. (3) intervention: we selected RCT studies as eligible studies, including both individual and cluster RCTs, as they provide the highest level of evidence for evaluating interventions.

The second round screening and selection concentrated on identifying specific strategies within the selected DHIs. A strategy is defined as a specific approach or technique employed within the intervention to promote health behavior change or improve health outcomes. We used framework of potential strategies (appendix 2) based on Behavior Change Techniques (BCTs)[39] and Behavior Strategies (BSs)[30].

The third round screening and selection focused on identifying the population with type 2 diabetes based on the second round work. A data extraction form was developed to facilitate electronic comparison of entries. The extracted data include the author, year of publication, study setting (country), characteristics of the participants, details of the interventions, strategies and outcomes. The inclusion criteria were as following:

1）Population

(1) Patients diagnosed with type 2 diabetes

(2) Age ≥ 18 years old

2) Comparisons

No digital health intervention

3) Outcomes

The outcome for the overview about the effectiveness of digital health intervention strategies included but not limited to acceptability, usability, satisfaction, appropriateness and efficiency. The outcome for the meta-analysis included the change of HbA1c, FBG, BMI, and weight loss.

4) Study design

We only included randomized controlled trials.

During the second and third screening, full manuscripts of the studies identified as potentially relevant were obtained and assessed by six independent reviewers according to the inclusion criteria. Any discrepancies were resolved by discussion or through adjudication by a senior researcher.

Quality appraisal

Two independent reviewers assessed the individual quality of the final selected sutdies using the Cochrane Collaboration Risk of Bias Tool[40], with any discrepancies being resolved by consensus. The quality evaluation items of each trial included selection bias (random sequence generation and allocation concealment), performance bias (blinding of participants and personnel), detection bias

(blinding of outcome assessment), attrition bias (incomplete outcome data), reporting bias (selective reporting), and other bias. These items were scored as low, high, or unclear risk of bias.

Data analysis and synthesis

Methods of analysis

Due to variability of some of the outcomes such as the change of physical activity, diabetes self-efficacy, diabetes medication adherence, quality of life, acceptability, satisfaction, etc. The meta-anlysis was not possible for these outcomes. Therefore, we reported a structured analysis of the findings to draw conclusions about the effectiveness of different DHI strategies on type 2 diabetes management. If a certain outcome measure has a statistically significant (P<0.05) improvement compared to the control group or over time, it was considered effective. If the outcome measures did not show significant changes over time or there was no statistically significant difference from the control group, it was considered that there was not enough evidence to prove their effectiveness. The synthesis framework for the assessment of health information technology (SF/HIT) was used to structure the evaluation of the studies because it included a whole system set of outcome variables[41]. These included adherence/attendance, acceptability, effectiveness, satisfaction, and perceived ease of use or usefulness, etc. In accordance with the framework, evidence for each of the outcome variables was coded as “positive or mixed” or “neutral or negative”. If the study did not address the outcome in question, it was coded as neutral or negative.

For the meta-analysis, the outcome included HbA1c, FBG, BMI, and weight loss. They were continuous variables, and thus network estimates was presented as the mean difference (MD) with a 95% confidence interval (CI). We assumed that a P Value < 0.05 indicated statistical significance. We measured the level of heterogeneity with the I^2 statistics; an I^2 < 50% was considered to have no significant heterogeneity, in which case we would use a fixed-effects model to calculate the pooled effect sizes. Otherwise, a random-effects model would be used. Stata 15.1 software (network package and network graphs package) was used to conduct network meta-analysis[42,43]. The network package performed the network meta-analysis based on the frequentist framework using random-effects models. The approach was to test the research hypothesis, as this was simpler than the problem of establishing prior probability[44]. This approach is not complex and has few limitations for ordinary researchers using network meta-analysis [45]. A network diagram with nodes and lines was constructed to represent different interventions, where the size of nodes represents the number of populations, and the thickness of lines between nodes represents the number of studies. The results of network meta-analysis were summarized based on all possible pairwise comparisons, including mixed comparisons (i.e., the combined effect of direct and indirect comparisons) and indirect comparisons. The effect of different interventions was estimated based on the surface under the cumulative ranking curve (SUCRA). The SUCRA value ranges from 0 to 100%, where a SUCRA value of 100% indicates that the treatment was the most effective, and the smaller the value, the poorer the treatment effect.

Assessment of inconsistency

The node-splitting test was used to assess the local inconsistency between direct and indirect comparisons. Differences between direct and indirect coefficients (via the P-value) were used to estimate inconsistency: if P < 0.05, local inconsistency existed[46]. If inconsistency was observed,

non-transitivity was suspected to also exist, and potential modifiers influencing treatment effect were examined.

Risk of bias across studies

The risk of publication bias in network meta-analysis was analyzed using the Egger's test[47]. The symmetry of the generated funnel plots was assessed visually using Egger's test, together with adjusted rank correlation and regression asymmetry tests[48,49].

Sensitivity analyses

We used the method of removing individual studies separately.

Results

The characteristics of included studies

The schematic flow for the selection of the included studies was shown in Figure 1. In total, 12372 studies were identified. Finally, only 52 trials[14,50–100] met the eligibility criteria and were included. The characteristics of the included studies were shown in appendix 3. Among the 52 included literatures, the publication year was between 2000 and 2023, with a slow increasing trend in publication, with the highest publication volume in 2022 and 2023. Most of the research came from the United States (20/52), followed by China (5/52). The minimum sample size was 30 and the maximum was 1926. The duration of intervention ranged from 3 to 24 months, with most studies lasting 12 months (15/52). The outcome indicators in intervention mainly included hemoglobin A1c level (HbA1c), fasting blood glucose (FBG), body mass index (BMI), blood pressure (BP), weight loss, waist circumference, low density lipoprotein cholesterol (LDL-C), high density lipoprotein cholesterol (HDL-C), total cholesterol (TC), diabetes self-efficiency, diabetes medication adherence, quality of life, self-management, depression, diabetes distress, and other outcomes.

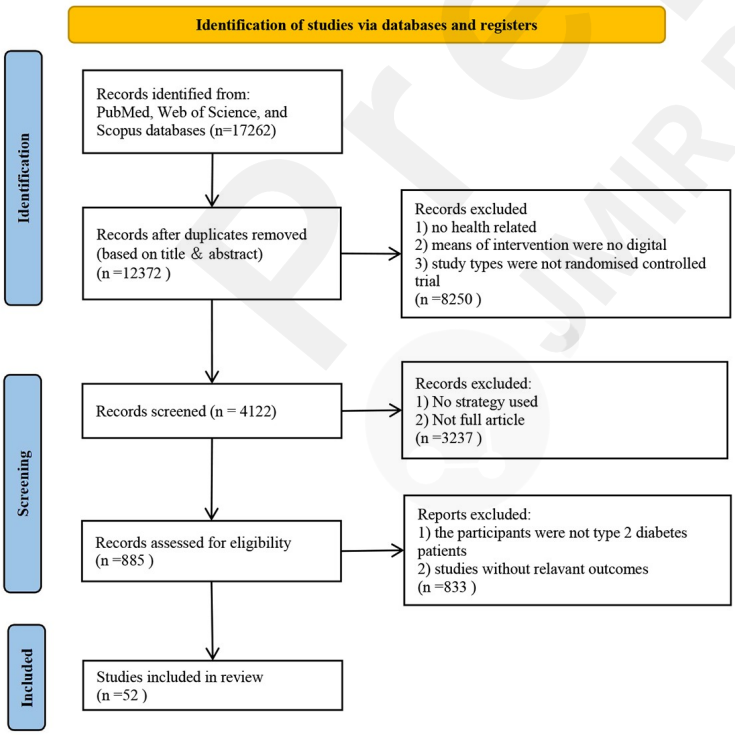


Figure 1. Flow diagram for the search and selection of the included studies.

Synthesis of different digital health intervention strategies

Among the 52 studies included, we identified a total of 63 different strategies, and they were

categorized into 19 themes. In the identified strategies, “monitor” and “guide” were the most frequently employed, accounting for 76.9% and 67.3% of total papers, respectively. Following closely were “management” (61.50%) and “engagement” (53.80%). More than 40% of the studies employed “stimulate”, “communication”, and “goal setting”, respectively. Additionally, over one-fifth of the research utilized “support”, “shape”, “feedback”, “prompt”, “action”, and “tailor”, respectively. The employment frequencies were notably lower for “cues”, “identity”, “reward”, “model/demonstrate”, and “restructure”. The studies ranged from utilizing a minimum of 1 to a maximum of 32 strategies. We categorized studies into three groups based on the number of strategies used: low (1-3 strategies), medium (4-6 strategies), and high (≥7 strategies). Among them, 18 studies were categorized as high-strategy study, 23 as medium-strategy study, and 11 as low-strategy. In these 52 studies, a total of 37 different combinations of strategies were identified based on the thematic strategies employed in each study. The detailed information about these strategies and strategy combinations were showed in appendix 4. The strategy themes and the number of identified study were shown in Table 1.

Table 1 The strategy themes and the number of identified study

	Theme	Number of identified study	Percentage of total studies
A	action planning	12	23.1%
B	communication	23	44.2%
C	cues	4	7.7%
D	engagement	28	53.8%
E	feedback	13	25%
F	goal setting	24	46.2%
G	guide	35	67.3%
H	identity	4	7.7%
I	management	32	61.5%
J	model/demonstrate	2	3.8%
K	monitor	40	76.9%
L	prompt	12	23.1%
M	restructure	2	3.8%
N	reward	4	7.7%
O	shape	15	28.8%
P	stimulate	22	42.3%
Q	support	19	36.5%
R	tailor	11	21.2%
S	others	7	13.5%

Evaluation of the effectiveness of different DHI strategies

In this assessment, we encoded positive or mixed as 1 and neutral or negative as 0. Overall, the majority of studies have reported positive or mixed outcomes for most outcome indicators. The number of positive or mixed results that studies achieved ranged from 6 to 11. A total of (41/52,78.7%) studies have reported having 10 or more positive or mixed results as stipulated in the SF/HIT. For the preventive care, efficiency, perceived ease of use/usefulness, safety/privacy/security, acceptability, appropriateness, and satisfaction domains, nearly all studies (greater than 50) have reported positive or mixed results. Following closely were process of service delivery/performance, effectiveness, and adherence/attendance, with (49/52), (47/52), and (45/52) reports of positive or

mixed results, respectively. However, in terms of cost effectiveness, the majority of studies (35/52, 67.3%) either did not report relevant results or reported neutral or negative findings. In high-strategy studies, (16/18, 88.9%) reported having 10 or more positive or mixed results. In medium-strategy studies, (20/23, 87%) reported having 10 or more positive or mixed results. However, in low-strategy studies, (7/11, 63.6%) reported having 10 or more positive or mixed results. Meanwhile, it is noteworthy that the two studies with the fewest positive or mixed results (n=6) were both high-strategy studies. The evaluation summary of SF/HIT results were presented in appendix 5.

Risk of bias and quality assessments of included studies

We conducted a synthesis of bias risk assessment results using RevMan 5.4 software (Cochrane). As shown in Figure 2. Overall, all included RCTs exhibited relatively low risk of bias. All studies reported the generation of random sequences and described specific randomization methods, assessed as low risk. There were no incomplete outcome data across all studies, assessed as low risk. Selective reporting was not observed in any of the studies, assessed as low risk. Regarding allocation concealment, (19/52) studies reported using this method, assessed as low risk, while 28/52 did not provide such reporting, assessed as unclear risk, and 5/52 studies explicitly stated not utilizing allocation concealment, assessed as high risk. For blinding of participants and personnel, the majority of studies (41/52) did not employ blinding, assessed as high risk, often due to the nature of the intervention precluding blinding. 8/52 studies implemented blinding for participants, assessed as low risk, while 3/52 studies did not report blinding status, assessed as unclear risk. For the blinding of outcome assessment, 24/52 studies did not employ blinding, resulting in high risk, whereas 17/52 studies reported using blinding for outcome assessment, assessed as low risk, with the remainder assessed as unclear risk. The risk of bias of each study were presented in appendix 6.

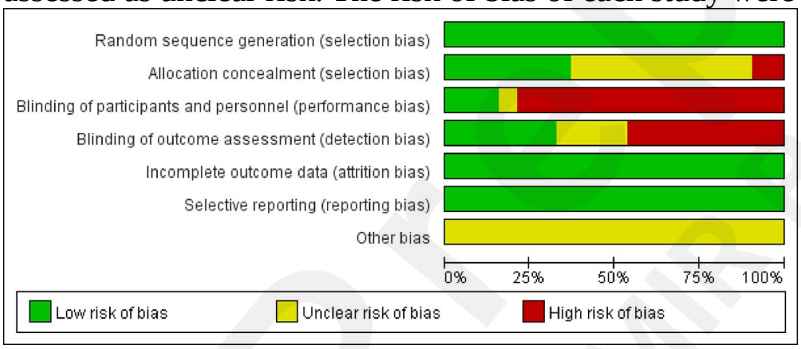


Figure 2. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

Meta analysis

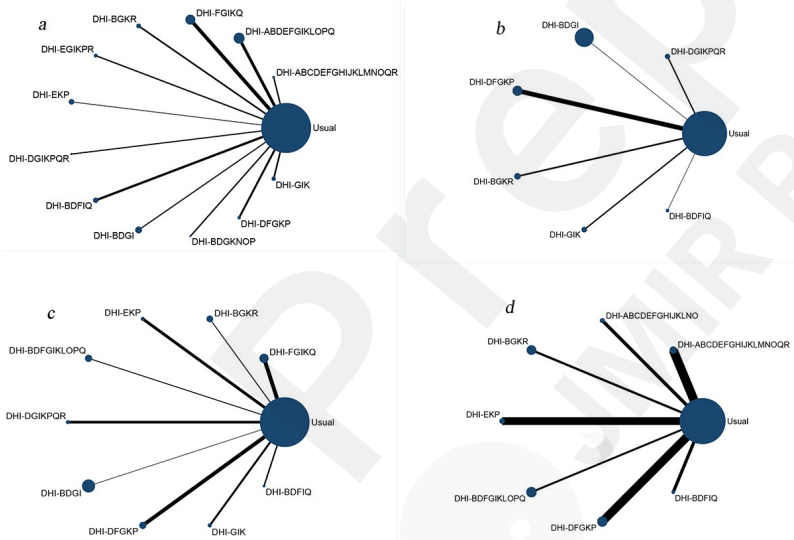
Analyses of the outcomes

(1) The effects of strategy combinations in reducing HbA1c

A total of 27 RCTs[14,50,53–55,57,59,60,66,68,70,72,74,77,78,80,82,84,85,87,88,93,94,96–98,100] assessed the effects of 12 different DHI strategy combinations on HbA1c levels in patients with type 2 diabetes. These 12 strategy combinations encompassed: (1) ABCDEFGHIJKLMNOQR (action planning, communication, cues, engagement, feedback, goal setting, guide, identity, management, model/demonstrate, monitor, prompt, restructure, reward, shape, support, tailor), (2) ABDEFGIKLOPQ (action planning, communication, engagement, feedback, goal setting, guide, management, monitor, prompt, shape, stimulate, support), (3) FGIKQ (goal setting, guide, management, monitor, support), (4)BGKR (communication, guide, monitor, tailor), (5) EGIKPR

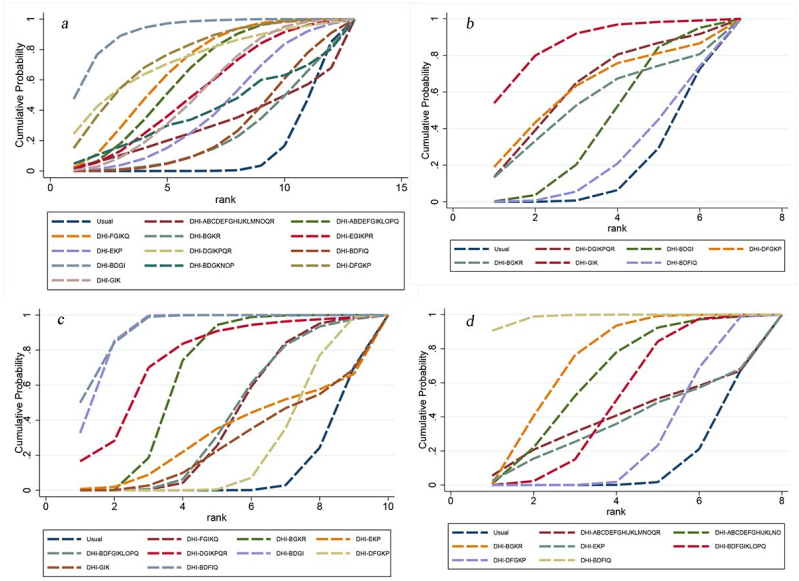
(feedback, guide, management, monitor, stimulate, tailor), (6) EKP (feedback, monitor, stimulate), (7) DGIKPQR (engagement, guide, management, monitor, stimulate, support, tailor), (8) BDFIQ (communication, engagement, goal setting, management, support), (9) BDGI (communication, engagement, guide, management), (10) BDGKNOP (communication, engagement, guide, monitor, reward, shape, stimulate), (11) DFGKP (engagement, goal setting, guide, monitor, stimulate), (12) GIK (guide, management, monitor).

The network evidence plot was shown in Figure 3. The SUCRA probability ranking for the reducing effect of HbA1c of different DHI strategy combinations was shown in Figure 4. For the 12 strategy combinations, the possibility of DHI-BDGI (communication, engagement, guide, management) being the best strategy combination was highest. The SUCRA value predicted the possibility of different strategy combinations as the best way, and the effects were ranked as follows: DHI-BDGI (91.8%) > DHI-DFGKP (76%) > DHI-DGIKPQR (73.2%) > DHI-FGIKQ (67.4%) > DHI-ABDEFGIKLOPQ (62.1%) > DHI-EGIKPR (52.8%) > DHI-GIK (52.1%) > DHI-EKP (40.5%) > DHI-BDGKNOP (39.4%) > DHI-ABCDEFGHIJKLMNOQR (30.1%) > DHI-BDFIQ (27.7%) > DHI-BGKR (24.1%) > Usual (12.8%). Compared with the usual care groups, DHI-BDGI (MD=−1.04, 95% CI −1.55 to −0.54), DHI-DFGKP (MD=−0.76, 95% CI −1.36 to −0.16), DHI-FGIKQ (MD=−0.61, 95% CI −1.01 to −0.22), DHI-ABDEFGIKLOPQ (MD=−0.55, 95% CI −0.92 to −0.18), and DHI-GIK (MD=−0.44, 95% CI −0.85 to −0.03) were statistically significantly effective in reducing HbA1c (Figure 5). Based on the interval estimation of direct and indirect comparison (Table 2 in appendix 7), DHI-BDGI was more effective than DHI-EKP, DHI-BDFIQ and DHI-BGKR.



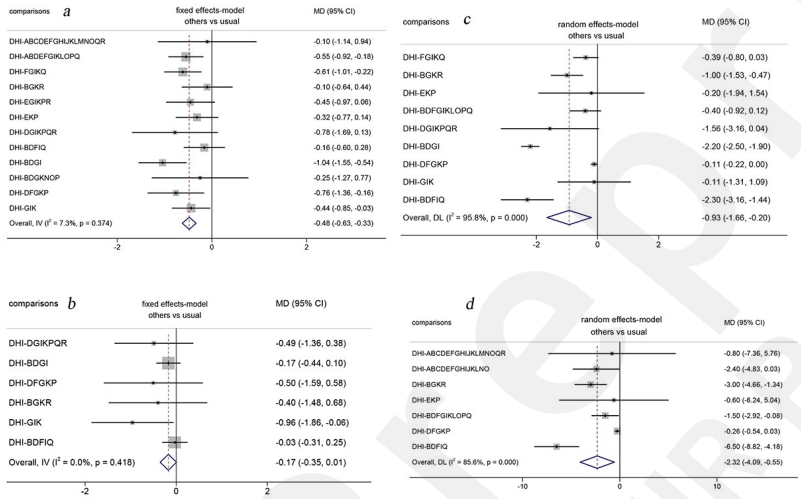
Note: a. HbA1c b. FBG c. BMI d. Weight loss

Figure 3. Evidence network of outcome indicators.



Note: a. HbA1c b. FBG c. BMI d. Weight loss

Figure 4. SUCRA rank of outcome indicators.



Note: a. HbA1c b. FBG c. BMI d. Weight loss

Figure 5. Forest plots of network meta-analysis results.

(2) The effects of strategy combinations on FBG

A total of 7 RCTs[74,78,84,85,87,97,98] assessed the effects of 6 different digital health intervention strategy combinations on FBG levels in patients with type 2 diabetes. These 6 strategy combinations encompassed: (1) DGIKPQR (engagement, guide, management, monitor, stimulate, support, tailor), (2) BDGI (communication, engagement, guide, management), (3) DFGKP (engagement, goal setting, guide, monitor, stimulate), (4) BGKR (communication, guide, monitor, tailor), (5) GIK (guide, management, monitor), (6) BDFIQ (communication, engagement, goal setting, management, support).

The network evidence plot was shown in Figure 3. The SUCRA probability ranking for the reducing effect of FBG of different DHI strategy combinations was shown in Figure 4. For the 6 strategy combinations, the possibility of DHI-GIK (guide, management, monitor) being the best strategy combination was highest. The SUCRA value predicted the possibility of different strategy combinations as the best way, and the effects were ranked as follows: DHI-GIK (86.7%) > DHI-DGIKPQR (62.8%) > DHI-DFGKP (61.6%) > DHI-BGKR (53.6%) > DHI-BDGI (42.7%) > DHI-

BDFIQ (24.4%) > Usual (18.2%). Compared with the usual care groups, only the DHI-GIK (MD=−0.96, 95% CI −1.86 to −0.06) was statistically significantly effective in reducing FBG (Figure 5). Based on the interval estimation of direct and indirect comparison (Table 3 in appendix 7), no strategy combination was superior to the others.

(3) The effects of strategy combinations on BMI

A total of 11 randomized controlled trials (RCTs) [60,66,70,72–74,78,84,85,97,98] assessed the effects of 9 different DHI strategy combinations on BMI levels in patients with type 2 diabetes. These 9 strategy combinations encompassed: (1) FGIKQ (goal setting, guide, management, monitor, support), (2) BGKR (communication, guide, monitor, tailor), (3) EKP (feedback, monitor, stimulate), (4) BDFGIKLOPQ (communication, engagement, goal setting, guide, management, monitor, prompt, shape, stimulate, support), (5) DGIKPQR (engagement, guide, management, monitor, stimulate, support, tailor), (6) BDGI (communication, engagement, guide, management), (7) DFGKP (engagement, goal setting, guide, monitor, stimulate), (8) GIK (guide, management, monitor), (9) BDFIQ (communication, engagement, goal setting, management, support).

The network evidence plot was shown in Figure 3. The SUCRA probability ranking for the reducing effect of BMI of different DHI strategy combinations was shown in Figure 4. For the 9 strategy combinations, DHI-BDFIQ (communication, engagement, goal setting, management, support) was most likely to be the optimal strategy combination. Based on the SUCRA values, the effects were ranked as follows: DHI-BDFIQ (92.6%) > DHI-BDGI (90.9%) > DHI-DGIKPQR (75.2%) > DHI-BGKR (65.1%) > DHI-BDFGIKLOPQ (41.4%) > DHI-FGIKQ (40.9%) > DHI-EKP (32%) > DHI-GIK (26.8%) > DHI-DFGKP (24.3%) > Usual (10.8%). Compared with the usual care groups, DHI-BDFIQ (MD=−2.30, 95% CI −3.16 to −1.44), DHI-BDGI (MD=−2.20, 95% CI −2.50 to −1.90) and DHI-BGKR (MD=−1.00, 95% CI −1.53 to −0.47) were statistically significantly effective in reducing BMI (Figure 51). Based on the interval estimation of direct and indirect comparison (Table 4 in appendix 7), DHI-BDFIQ was superior to all other strategy combinations except for DHI-BDGI and DHI-DGIKPQR. In addition, except for DHI-BDFIQ and DHI-DGIKPQR, DHI-BDGI was superior to the rest of strategy combinations. DHI-BGKR was also superior to DHI-DFGKP.

(4) The effects of strategy combinations on weight loss

A total of 8 RCTs[50,52,70,72,73,84,85,98] assessed the effects of 7 different DHI strategy combinations on weight loss in patients with type 2 diabetes. These 7 strategy combinations encompassed: (1) ABCDEFGHIJKLMNOQR (action planning, communication, cues, engagement, feedback, goal setting, guide, identity, management, model/demonstrate, monitor, prompt, restructure, reward, shape, support, tailor), (2) ABCDEFGHIJKLNO (action planning, communication, cues, engagement, feedback, goal setting, guide, identity, management, model/demonstrate, monitor, prompt, reward, shape), (3) BGKR (communication, guide, monitor, tailor), (4) EKP (feedback, monitor, stimulate), (5) BDFGIKLOPQ (communication, engagement, goal setting, guide, management, monitor, prompt, shape, stimulate, support), (6) DFGKP (engagement, goal setting, guide, monitor, stimulate), (7) BDFIQ (communication, engagement, goal setting, management, support).

The network evidence plot was shown in Figure 3. The SUCRA probability ranking for the effect of weight loss of different DHI strategy combinations was shown in Figure 4. For the 7 strategy combinations, DHI-BDFIQ (communication, engagement, goal setting, management, support) was most likely to be the optimal strategy combination. Based on the SUCRA values, the effects were ranked as follows: DHI-BDFIQ (98.5%) > DHI-BGKR (72.9%) > DHI-ABCDEFGHIJKLNO (63%) > DHI-BDFGIKLOPQ (49.8%) > DHI-ABCDEFGHIJKLMNOQR (39.2%) > DHI-EKP (36.2%) > DHI-DFGKP (27.5%) > Usual (12.9%). Compared with the usual care groups, DHI-BDFIQ

(MD=−6.50, 95% CI −8.82 to −4.18), DHI-BGKR (MD=−3.00, 95% CI −4.66 to −1.34) and DHI-BDFGIKLOPQ (MD=−1.50, 95% CI −2.92 to −0.08) were statistically significantly effective in weight loss (Figure 5). Based on the interval estimation of direct and indirect comparison (Table 5 in appendix 7), DHI-BDFIQ was superior to DHI-BGKR, DHI-ABCDEFGHIJKLNO, DHI-BDFGIKLOPQ, and DHI-DFGKP . Additionally, DHI-BGKR was also superior to DHI-DFGKP.

Heterogeneity and consistency analysis

The global inconsistency and local inconsistency with the node-splitting test was conducted for inconsistency analysis. The results showed no statistical inconsistency in each outcome comparisons (P□0.05). High heterogeneity between studies was only observed in BMI and weight loss outcomes. However, we did not find significant publication bias for these two outcomes thourgh the Egger test (P=0.289 for BMI, and P=0.106 for weight loss). The net split function analyses found no statistically significant inconsistencies when assessing differences between direct and indirect effects. More details were showed in Table 6 in appendix 7.

Assessment of publication bias

We conducted a comparison-adjusted funnel plots of trials included in the network meta-analysis for each result (Figure 6 in appendix 7), and the included studies were generally symmetrically distributed in the upper and middle parts of the funnel, around the left and right sides of the midline, indicating a low possibility of publication bias. Individual studies were distributed at the bottom, which may be related to the small sample size.

Sensitivity analysis

We used the method of removing individual studies separately. Our results were generally stable and credible. The details were showed in Figure 7 in appendix 7.

Discussion

Our study offered a comprehensive insight into the strategies employed in DHIs on type 2 diabetes management. Firsty, a total of 63 different strategies and 19 strategy themes were identified through 52 RCTs. In the identified strategies, “monitor” and “guide” were the most frequently employed, accounting for 76.9% and 67.3% of total papers, respectively. Following closely were “management” (61.50%) and “engagement” (53.80%). The frequency of the use of these strategies indicates the trend and focus in this field. First of all, “monitor” reflects the role of digital tools in monitoring patients' physiological indicators and behavior habits in diabetes management. It allows doctors and patients to track key parameters such as blood glucose level, weight, exercise volume, etc. in real time, which helps to adjust the treatment plan in time and reduce the risk of complications[101]. Secondly, the use of “guide” reflects the value of digital health management in providing personalized and real-time advice and guidance to patients. Through intelligent algorithms and personalized settings, digital platforms can provide patients with accurate nutritional advice, exercise plans, and medication guidance based on their individual characteristics and historical data, helping them better manage their diseases and improve treatment outcomes[102]. These results are consistent with prior research that highlights the crucial role of “monitor” and “guide” in DHIs[103,104]. On this basis, “management” emphasizes the important role of digital platforms in assisting doctors in disease management and treatment decision-making. Through data analysis and predictive models, digital platforms can provide doctors with more comprehensive and timely patient information, help them develop more effective treatment plans, and improve the accuracy and efficiency of clinical

decision-making[105]. Furthermore, “engagement” emphasizes the promoting role of digital health management in patient participation and self-management. By providing personalized educational content, social support, and behavioral motivation, digital platforms can stimulate patients' treatment motivation, enhance their awareness and self-management abilities towards the disease, thereby improving treatment compliance and long-term efficacy[106].

The number of strategies used in each study varies greatly, ranging from 1 to 32. Among them, 18 (34.6%) studies were categorized as high-strategy study, 23 (44.2%) as medium-strategy study, and 11 (21.2%) as low-strategy study. In digital health management, the use of different numbers of strategies in research may reflect the diversity of research design, objectives, and methods. Many studies have chosen a medium number of strategies to comprehensively consider multiple aspects and evaluate the effectiveness of disease management. Research using low quantity strategies may focus more on the intervention effects in specific aspects to further explore the mechanisms of action of specific strategies. On the contrary, studies using high quantity strategies may aim to explore the combined effects of multiple intervention methods in order to achieve more comprehensive disease management. However, the results of the studies we included did not indicate that more strategies have more effective effects. Therefore, we further evaluated the impact of different number strategies and compared the effect of different strategy combinations, so as to provide more practical guidance for accurate and personalized digital health management.

We assessed the effectiveness of DHI strategies qualitatively based on the synthesis framework for the assessment of health information technology (SF/HIT). Overall, the majority of studies have reported positive or mixed outcomes for most outcome indicators, such as preventive care, efficiency, perceived ease of use/usefulness, safety/privacy/security, acceptability, appropriateness, satisfaction process of service delivery/performance, effectiveness, and adherence/attendance. However, in terms of cost-effectiveness, most studies have not reported positive results. This may be due to the introduction and development of digital health management tools, which provide more convenient, safe and efficient management methods for diabetes patients[60]. These tools include remote monitoring devices, mobile applications, and online platforms that can help patients better monitor blood glucose, manage diet, exercise, etc., thereby improving the effectiveness of preventive care and improving service delivery processes, enhancing patient acceptance and satisfaction with treatment plans[105]. However, the negative results in terms of cost-effectiveness may be due to the significant investment required for the implementation and operation of digital health management tools, and the long-term cost-effectiveness has not been fully demonstrated[59,62,73]. In high-strategy and medium-strategy studies, most studies report positive outcomes, while low-strategy studies report fewer positive outcomes. This reflects the investment of more resources and technology, which can more comprehensively meet the needs of patients and improve treatment effectiveness. In contrast, low-strategy research may not achieve the same effect due to resource constraints or insufficient technology. This was consistent with research[35] that indicates using a combination of strategies, rather than a single approach, can be more effective in enhancing participant retention. Future research should focus on cost-effectiveness analysis, explore the long-term economic benefits of digital health management tools, and propose more effective low-cost

strategies to promote the sustainable development of diabetes management strategies.

In the meta analysis, we included 27 studies evaluating the efficacy of 12 different DHI strategy combinations on HbA1c levels. We found several high-quality combinations that can significantly reduce the HbA1c levels, which reflects that in diabetes management, a specific strategy combination may have more advantages than a single strategy. Among numerous strategy combinations, the SUCRA probability ranking suggested that DHI-BDGI (communication, engagement, guide, management) might be the most effective strategy combination, followed by DHI-DFGKP (engagement, goal setting, guide, monitor, stimulate), DHI-FGIKQ (goal setting, guide, management, monitor, support), and DHI-ABDEFGIKLOPQ (action planning, communication, engagement, feedback, goal setting, guide, management, monitor, prompt, shape, stimulate, support). The effect of only using the combination of DHI-GIK (guide, management, monitor) was relatively weak. First of all, in the current medical practice, the treatment of diabetes is no longer a simple drug treatment, but a comprehensive management, including lifestyle intervention, psychological support, drug treatment and other comprehensive interventions[5]. Among them, communication and patient engagement are considered crucial factors, which can enhance patients' understanding and compliance with treatment, and improve treatment effectiveness[106]. Meanwhile, guidance and management provide specific action guidelines and treatment plans to help patients better control their blood glucose levels[102,105]. The combination of these strategies complements each other and can comprehensively cover all aspects of the treatment process, maximizing the therapeutic effect. Secondly, these two combinations DHI-DFGKP (engagement, goal setting, guide, monitor, stimulate) and DHI-FGIKQ (goal setting, guide, management, monitor, support) also showed good results. They emphasize aspects such as patient engagement, goal setting, guidance, monitoring, and support. The combination of these strategies makes the treatment process more systematic and orderly, helping patients better understand and execute treatment plans, and improving the success rate of treatment[59]. However, the combination DHI-ABDEFGIKLOPQ (action planning, communication, engagement, feedback, goal setting, guide, management, monitor, prompt, shape, stimulate, support) encompasses more strategies and may seem more comprehensive, but there may be some challenges in practical applications. This complex combination may require more resources and time to implement, while also increasing the cognitive burden on patients, which may affect treatment compliance. Finally, the combination DHI-GIK (guide, management, monitor) that only include a few strategies was relatively weak. This may be due to a lack of communication and patient engagement, reflecting insufficient communication between healthcare professionals and patients in real clinical practice, and a lack of enthusiasm and participation from patients in treatment[78,106]. In addition, relying solely on guidance and management, while ignoring the psychological and lifestyle factors of patients, can also easily lead to poor treatment outcomes.

At the same time, we included 7 studies evaluating the efficacy of 6 different DHI strategy combinations on FBG. Only DHI-GIK (guide, management, monitor) was shown to have an effect. The advantage of this effective strategy combinationis that it integrates three key elements: guidance, management, and monitoring. These strategies can provide systematic treatment support, help

patients develop and execute effective treatment plans, and monitor treatment outcomes in a timely manner, thereby better controlling FBG levels[97]. Our result was consistent with research that has shown that multi-dimensional interventions, including guidance, management and monitoring, are critical to the success of diabetes management[5]. However, other strategy combinations may lack sustained guidance and monitoring, or may not fully motivate patients to actively participate in treatment, resulting in poor effect compared with DHI-GIK (guide, management, monitor). Meanwhile, this result may also be influenced by the bias caused by the insufficient amount of original studies on FBG in our meta analysis. Therefore, there is a certain difference in the results between it and HbA1c.

In general, our research results highlight the importance of comprehensive strategy combination in blood glucose management of type 2 diabetes. Future research can further explore other combinations of strategies to find more effective management models for diabetes. There is a need to strengthen communication and interaction between healthcare professionals and patients, as well as to improve patient participation and compliance. Furthermore, it is essential to strengthen the long-term tracking and evaluation of diabetes management strategies.

This review showed that DHI-BDFIQ (communication, engagement, goal setting, management, support) and DHI-BGKR (communication, guide, monitor, tailor) were significantly effective for both BMI and weight loss. Among them, DHI-BDFIQ (communication, engagement, goal setting, management, support) was considered the optimal combination. Firstly, it covers several key aspects: effective communication promotes cooperation and understanding between patients and medical teams; active engagement enhances the patient's participation and execution of treatment such as physical activity and dietary intake control; clear goal setting helps guide the direction and progress of treatment[98]; effective management can provide systematic treatment plans and continuous management support; and continuous support can help patients overcome difficulties and maintain a positive attitude during the treatment process[59], so as to help patients better manage their weight. On the other hand, DHI-BGKR (communication, guide, monitor, tailor) emphasizes personalized guidance and monitoring, which is more targeted, allowing patients to adjust their weight management plan according to their own situation[56,64,70], thereby reducing weight and BMI. In addition, DHI-BDGI (communication, engagement, guide, management) was found to be effective for BMI and DHI-BDFGIKLOPQ (communication, engagement, goal setting, guide, management, monitor, prompt, shape, stimulate, support) was effective for weight loss, respectively. Our research results have indicated that DHI-BDGI (communication, engagement, guide, management) was the most effective in reducing the HbA1c, and therefore it has a good effect on controlling BMI. Studies have shown that comprehensive treatment plans, including communication, engagement, guidance and management, can effectively improve blood glucose control and weight management in patients with type 2 diabetes[107,108]. The effectiveness of these strategies may stem from their ability to comprehensively influence the patient's lifestyle and behavioral habits, thereby promoting the achievement of treatment goals[73,79,94]. The combination DHI-BDFGIKLOPQ (communication, engagement, goal setting, guide, management, monitor, prompt, shape, stimulate, support) includes multiple strategies, from goal setting to behavior shaping and support, having a good effect on

weight loss, but may encounter some challenges in practical applications. Therefore, the effect was relatively weak.

Our research emphasizes the advantages of the combination of communication, patient engagement, goal setting, personalized management, external support and continuous monitoring strategies in the DHI of BMI and weight management of type 2 diabetes patients. Future research can further explore the applicability of these strategy combinations in different outcomes such as quality of life, complication rate and other indicators. In addition, precise personalized intervention based on artificial intelligence and big data analysis is necessary. At the same time, more interactive and personalized digital health platforms can be developed to improve patient engagement and treatment compliance.

Limitations

This study has several limitations. Firstly, despite conducting a comprehensive search, it's possible that some relevant papers published in non-English languages or from non-indexed sources might have been overlooked. Secondly, we conducted three rounds of data screening and extraction, which could introduce inconsistencies in certain cases. Additionally, in our quantitative analysis, we only performed meta-analyses on specific outcome measures, thereby limiting the generalizability of our conclusions. Regarding BMI and weight loss outcomes, there was substantial heterogeneity among studies, but we provided explanations through sensitivity analyses and publication bias assessments. Furthermore, the number of original studies included in the meta-analyses was relatively small, potentially leading to some degree of bias in the conclusions. Lastly, due to the nature of the interventions, blinding was not feasible in the majority of studies. This might exaggerate estimated intervention effects in the network meta-analysis and contribute to low-to-moderate quality of the evidence and a low methodology quality of included studies.

Conclusions

Our research provided a comprehensive analysis and summary of the strategies used in DHIs of type 2 diabetes. We identified 63 strategies and categorized them into 19 strategy themes. *Guide*, *monitor*, *management*, and *engagement* were the most commonly used strategies. Most studies have reported positive or mixed outcomes for most outcome indicators based on the SF/HIT. Research involving a medium or high quantity of strategies was found to be more effective than research involving a low quantity of strategies. The strategy combination composed of *communication*, *engagement*, *guide*, and *management* was most effective in reducing HbA1c, while the strategy combination that included *guide*, *management*, and *monitor* was effective in reducing FBG. Strategy combination composed of *communication*, *engagement*, *goal setting*, *management*, and *support* was most effective in BMI and weight management. Future research should further confirm the effectiveness of these strategies in other indicators and populations, explore more strategy combinations, and optimize the design and implementation of strategies for diabetes patients. It is also necessary to develop more interactive and personalized digital health platforms. Finally, the cost-effectiveness analysis of strategy use should be strengthened to provide more effective guidance for disease management and clinical practice of type 2 diabetes.

Acknowledgements
This study was supported by the Key Research & Development Plan of Shaanxi Province, China (2021SF-144) and National Higher Medical Education Association, Nursing Education Branch, Education Science Fund Project (GJHL160008). We also sincerely appreciate all the authors who participated in this systematic review and meta-analysis.

Conflicts of Interest
None declared.

Abbreviations
BMI: body mass index
BCTs: behavior change techniques
BSs: behavior strategies
CI: confidence interval
DHIs: digital health interventions
FBG: fasting blood glucose
HbA1c: glycated hemoglobin A1c
MD: mean difference
QoL: quality of life
RCTs: randomized controlled trials
SF/HIT: synthesis framework for the assessment of health information technology
SMS: short message service
SUCRA: surface under the cumulative ranking curve
T2DM: type 2 diabetes mellitus

Multimedia Appendix 1. Search strategy
Multimedia Appendix 2. Behavior Change Techniques (BCTs)
Multimedia Appendix 3. The characteristics of the included studies
Multimedia Appendix 4. The detailed information about strategies and strategy combinations
Multimedia Appendix 5. Evaluation of the effectiveness of different DHI strategies based on SF-HIT
Multimedia Appendix 6. Risk of bias and quality assessments of included studies
Multimedia Appendix 7. Supplementary materials

References
1. Väätäinen S, Keinänen-Kiukaanniemi S, Saramies J, Uusitalo H, Tuomilehto J, Martikainen J. Quality of life along the diabetes continuum: a cross-sectional view of health-related quality of life and general health status in middle-aged and older Finns. Quality of Life Research: An International Journal of Quality of Life Aspects of Treatment, Care and Rehabilitation 2014 Sep;23(7):1935–1944. PMID:24510623
2. Jalkanen K, Aarnio E, Lavikainen P, Jauhonen H-M, Enlund H, Martikainen J. Impact of type 2 diabetes treated with non-insulin medication and number of diabetes-coexisting diseases on EQ-5D-5 L index scores in the Finnish population. Health Qual Life Outcomes 2019 Jul 8;17(1):117. doi: 10.1186/s12955-019-1187-9

3. Williams R, Karuranga S, Malanda B, Saeedi P, Basit A, Besançon S, Bommer C, Esteghamati A, Ogurtsova K, Zhang P, Colagiuri S. Global and regional estimates and projections of diabetes-related health expenditure: Results from the International Diabetes Federation Diabetes Atlas, 9th edition. Diabetes Res Clin Pract 2020 Apr;162:108072. doi: 10.1016/j.diabres.2020.108072
4. Magliano DJ, Boyko EJ, IDF Diabetes Atlas 10th edition scientific committee. IDF DIABETES ATLAS. 10th ed. Brussels: International Diabetes Federation; 2021. PMID:35914061ISBN:978-2-930229-98-0
5. Chinese Elderly Type 2 Diabetes Prevention and Treatment of Clinical Guidelines Writing Group, Geriatric Endocrinology and Metabolism Branch of Chinese Geriatric Society, Geriatric Endocrinology and Metabolism Branch of Chinese Geriatric Health Care Society, Geriatric Professional Committee of Beijing Medical Award Foundation, National Clinical Medical Research Center for Geriatric Diseases (PLA General Hospital). [Clinical guidelines for prevention and treatment of type 2 diabetes mellitus in the elderly in China (2022 edition)]. Zhonghua Nei Ke Za Zhi 2022 Jan 1;61(1):12–50. PMID:34979769
6. American Diabetes Association. 4. Comprehensive Medical Evaluation and Assessment of Comorbidities: Standards of Medical Care in Diabetes-2021. Diabetes Care 2021 Jan;44(Suppl 1):S40–S52. doi: 10.2337/dc21-S004
7. Bain SC, Bekker Hansen B, Hunt B, Chubb B, Valentine WJ. Evaluating the burden of poor glycemic control associated with therapeutic inertia in patients with type 2 diabetes in the UK. Journal of Medical Economics 2020 Jan;23(1):98–105. doi: 10.1080/13696998.2019.1645018
8. Fellinger P, Rodewald K, Ferch M, Itariu B, Kautzky-Willer A, Winhofer Y. HbA1c and Glucose Management Indicator Discordance Associated with Obesity and Type 2 Diabetes in Intermittent Scanning Glucose Monitoring System. Biosensors 2022 Apr 29;12(5):288. PMID:35624589
9. GBD 2015 Obesity Collaborators, Afshin A, Forouzanfar MH, Reitsma MB, Sur P, Estep K, Lee A, Marczak L, Mokdad AH, Moradi-Lakeh M, Naghavi M, Salama JS, Vos T, Abate KH, Abbafati C, Ahmed MB, Al-Aly Z, Alkerwi A, Al-Raddadi R, Amare AT, Amberbir A, Amegah AK, Amini E, Amrock SM, Anjana RM, Ärnlöv J, Asayesh H, Banerjee A, Barac A, Baye E, Bennett DA, Beyene AS, Biadgilign S, Biryukov S, Bjertness E, Boneya DJ, Campos-Nonato I, Carrero JJ, Cecilio P, Cercy K, Ciobanu LG, Cornaby L, Damtew SA, Dandona L, Dandona R, Dharmaratne SD, Duncan BB, Eshrati B, Esteghamati A, Feigin VL, Fernandes JC, Fürst T, Gebrehiwot TT, Gold A, Gona PN, Goto A, Habtewold TD, Hadush KT, Hafezi-Nejad N, Hay SI, Horino M, Islami F, Kamal R, Kasaeian A, Katikireddi SV, Kengne AP, Kesavachandran CN, Khader YS, Khang Y-H, Khubchandani J, Kim D, Kim YJ, Kinfu Y, Kosen S, Ku T, Defo BK, Kumar GA, Larson HJ, Leinsalu M, Liang X, Lim SS, Liu P, Lopez AD, Lozano R, Majeed A, Malekzadeh R, Malta DC, Mazidi M, McAlinden C, McGarvey ST, Mengistu DT, Mensah GA, Mensink GBM, Mezgebe HB, Mirrakhimov EM, Mueller UO, Noubiap JJ, Obermeyer CM, Ogbo FA, Owolabi MO, Patton GC, Pourmalek F, Qorbani M, Rafay A, Rai RK, Ranabhat CL, Reinig N, Safiri S, Salomon JA, Sanabria JR, Santos IS, Sartorius B, Sawhney M, Schmidhuber J, Schutte AE, Schmidt MI, Sepanlou SG, Shamsizadeh M, Sheikhbahaei S, Shin M-J, Shiri R, Shiue I, Roba HS, Silva DAS, Silverberg JI, Singh JA, Stranges S, Swaminathan S, Tabarés-Seisdedos R, Tadese F, Tedla BA, Tegegne BS, Terkawi AS, Thakur JS, Tonelli M, Topor-Madry R, Tyrovolas S, Ukwaja KN, Uthman OA, Vaezghasemi M, Vasankari T, Vlassov VV, Vollset SE, Weiderpass E, Werdecker A, Wesana J, Westerman R, Yano Y, Yonemoto N, Yonga G, Zaidi Z, Zenebe ZM, Zipkin B, Murray CJL. Health Effects of Overweight and Obesity in 195 Countries over 25 Years. N Engl J Med 2017 Jul 6;377(1):13–27. PMID:28604169
10. Holman RR, Paul SK, Bethel MA, Matthews DR, Neil HAW. 10-year follow-up of intensive glucose control in type 2 diabetes. N Engl J Med 2008 Oct 9;359(15):1577–1589. PMID:18784090
11. Lean ME, Leslie WS, Barnes AC, Brosnahan N, Thom G, McCombie L, Peters C,

Zhyzhneuskaya S, Al-Mrabeh A, Hollingsworth KG, Rodrigues AM, Rehackova L, Adamson AJ, Sniehotta FF, Mathers JC, Ross HM, McIlvenna Y, Stefanetti R, Trenell M, Welsh P, Kean S, Ford I, McConnachie A, Sattar N, Taylor R. Primary care-led weight management for remission of type 2 diabetes (DiRECT): an open-label, cluster-randomised trial. Lancet (London, England) 2018 Feb 10;391(10120):541–551. PMID:29221645

12. Johansen MY, MacDonald CS, Hansen KB, Karstoft K, Christensen R, Pedersen M, Hansen LS, Zacho M, Wedell-Neergaard A-S, Nielsen ST, Iepsen UW, Langberg H, Vaag AA, Pedersen BK, Ried-Larsen M. Effect of an Intensive Lifestyle Intervention on Glycemic Control in Patients With Type 2 Diabetes: A Randomized Clinical Trial. Jama 2017 Aug 15;318(7):637–646. PMID:28810024

13. Gong Q, Zhang P, Wang J, Ma J, An Y, Chen Y, Zhang B, Feng X, Li H, Chen X, Cheng YJ, Gregg EW, Hu Y, Bennett PH, Li G, Da Qing Diabetes Prevention Study Group. Morbidity and mortality after lifestyle intervention for people with impaired glucose tolerance: 30-year results of the Da Qing Diabetes Prevention Outcome Study. The Lancet Diabetes & Endocrinology 2019 Jun;7(6):452–461. PMID:31036503

14. Lee EY, Cha S-A, Yun J-S, Lim S-Y, Lee J-H, Ahn Y-B, Yoon K-H, Hyun MK, Ko S-H. Efficacy of Personalized Diabetes Self-care Using an Electronic Medical Record-Integrated Mobile App in Patients With Type 2 Diabetes: 6-Month Randomized Controlled Trial. J Med Internet Res 2022 Jul 28;24(7):e37430. doi: 10.2196/37430

15. Quinn CC, Shardell MD, Terrin ML, Barr EA, Ballew SH, Gruber-Baldini AL. Cluster-randomized trial of a mobile phone personalized behavioral intervention for blood glucose control. Diabetes Care 2011 Sep;34(9):1934–1942. doi: 10.2337/dc11-0366

16. Holmen H, Torbjørnsen A, Wahl AK, Jenum AK, Småstuen MC, Arsand E, Ribu L. A Mobile Health Intervention for Self-Management and Lifestyle Change for Persons With Type 2 Diabetes, Part 2: One-Year Results From the Norwegian Randomized Controlled Trial RENEWING HEALTH. JMIR mHealth and uHealth 2014 Dec 11;2(4):e57. doi: 10.2196/mhealth.3882

17. Kirwan M, Vandelanotte C, Fenning A, Duncan MJ. Diabetes self-management smartphone application for adults with type 1 diabetes: randomized controlled trial. J Med Internet Res 2013 Nov 13;15(11):e235. doi: 10.2196/jmir.2588

18. Waki K, Fujita H, Uchimura Y, Omae K, Aramaki E, Kato S, Lee H, Kobayashi H, Kadowaki T, Ohe K. DialBetics: A Novel Smartphone-based Self-management Support System for Type 2 Diabetes Patients. Journal of Diabetes Science and Technology 2014 Mar;8(2):209–215. PMID:24876569

19. Rhee SY, Kim C, Shin DW, Steinhubl SR. Present and Future of Digital Health in Diabetes and Metabolic Disease. Diabetes & Metabolism Journal 2020 Dec;44(6):819–827. doi: 10.4093/dmj.2020.0088

20. Arora S, Peters AL, Burner E, Lam CN, Menchine M. Trial to examine text message-based mHealth in emergency department patients with diabetes (TExT-MED): a randomized controlled trial. Ann Emerg Med 2014 Jun;63(6):745-754.e6. doi: 10.1016/j.annemergmed.2013.10.012

21. Hutchesson MJ, Rollo ME, Krukowski R, Ells L, Harvey J, Morgan PJ, Callister R, Plotnikoff R, Collins CE. eHealth interventions for the prevention and treatment of overweight and obesity in adults: a systematic review with meta-analysis. Obesity Reviews: An Official Journal of the International Association for the Study of Obesity 2015 May;16(5):376–392. PMID:25753009

22. Sherrington A, Newham JJ, Bell R, Adamson A, McColl E, Araujo-Soares V. Systematic review and meta-analysis of internet-delivered interventions providing personalized feedback for weight loss in overweight and obese adults. Obesity Reviews: An Official Journal of the International Association for the Study of Obesity 2016 Jun;17(6):541–551. PMID:26948257

23. Ramadas A, Quek KF, Chan CKY, Oldenburg B. Web-based interventions for the management of type 2 diabetes mellitus: a systematic review of recent evidence. Int J Med Inf 2011 Jun;80(6):389–405. doi: 10.1016/j.ijmedinf.2011.02.002

24. Van Rhoon L, Byrne M, Morrissey E, Murphy J, McSharry J. A systematic review of the

behaviour change techniques and digital features in technology-driven type 2 diabetes prevention interventions. Digital Health 2020;6:2055207620914427. PMID:32269830
25. Webb TL, Joseph J, Yardley L, Michie S. Using the internet to promote health behavior change: a systematic review and meta-analysis of the impact of theoretical basis, use of behavior change techniques, and mode of delivery on efficacy. J Med Internet Res 2010 Feb 17;12(1):e4. doi: 10.2196/jmir.1376
26. Michie S, Yardley L, West R, Patrick K, Greaves F. Developing and Evaluating Digital Interventions to Promote Behavior Change in Health and Health Care: Recommendations Resulting From an International Workshop. J Med Internet Res 2017 Jun 29;19(6):e232. doi: 10.2196/jmir.7126
27. Riley WT, Rivera DE, Atienza AA, Nilsen W, Allison SM, Mermelstein R. Health behavior models in the age of mobile interventions: are our theories up to the task? Translational Behavioral Medicine 2011 Mar;1(1):53–71. doi: 10.1007/s13142-011-0021-7
28. Morrison LG, Yardley L, Powell J, Michie S. What design features are used in effective e-health interventions? A review using techniques from Critical Interpretive Synthesis. Telemedicine Journal and E-Health: The Official Journal of the American Telemedicine Association 2012 Mar;18(2):137–144. PMID:22381060
29. Saleem M, Kühne L, De Santis KK, Christianson L, Brand T, Busse H. Understanding Engagement Strategies in Digital Interventions for Mental Health Promotion: Scoping Review. JMIR mental health 2021 Dec 20;8(12):e30000. doi: 10.2196/30000
30. Lim S, Hill B, Pirotta S, O'Reilly S, Moran L. What Are the Most Effective Behavioural Strategies in Changing Postpartum Women's Physical Activity and Healthy Eating Behaviours? A Systematic Review and Meta-Analysis. Journal of Clinical Medicine 2020 Jan 16;9(1):237. doi: 10.3390/jcm9010237
31. Masi CM, Chen H-Y, Hawkley LC, Cacioppo JT. A meta-analysis of interventions to reduce loneliness. Personality and Social Psychology Review: An Official Journal of the Society for Personality and Social Psychology, Inc 2011 Aug;15(3):219–266. PMID:20716644
32. Mair JL, Salamanca-Sanabria A, Augsburger M, Frese BF, Abend S, Jakob R, Kowatsch T, Haug S. Effective Behavior Change Techniques in Digital Health Interventions for the Prevention or Management of Noncommunicable Diseases: An Umbrella Review. Ann Behav Med 2023 Aug 25;57(10):817–835. PMID:37625030
33. Hwang DA, Lee A, Song JM, Han H-R. Recruitment and Retention Strategies Among Racial and Ethnic Minorities in Web-Based Intervention Trials: Retrospective Qualitative Analysis. J Med Internet Res 2021 Jul 12;23(7):e23959. doi: 10.2196/23959
34. Treweek S, Pitkethly M, Cook J, Fraser C, Mitchell E, Sullivan F, Jackson C, Taskila TK, Gardner H. Strategies to improve recruitment to randomised trials. Cochrane Db Syst Rev 2018 Feb 22;2(2):MR000013. PMID:29468635
35. Brueton VC, Tierney J, Stenning S, Harding S, Meredith S, Nazareth I, Rait G. Strategies to improve retention in randomised trials. Cochrane Db Syst Rev 2013 Dec 3;(12):MR000032. PMID:24297482
36. Robinson KA, Dennison CR, Wayman DM, Pronovost PJ, Needham DM. Systematic review identifies number of strategies important for retaining study participants. J Clin Epidemiol 2007 Aug;60(8):757–765. doi: 10.1016/j.jclinepi.2006.11.023
37. Lee SWH, Chan CKY, Chua SS, Chaiyakunapruk N. Comparative effectiveness of telemedicine strategies on type 2 diabetes management: A systematic review and network meta-analysis. Sci Rep 2017 Oct 4;7:12680. PMID:28978949
38. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R, Glanville J, Grimshaw JM, Hróbjartsson A, Lalu MM, Li T, Loder EW, Mayo-Wilson E, McDonald S, McGuinness LA, Stewart LA, Thomas J, Tricco AC, Welch VA, Whiting P, Moher D. The PRISMA 2020 statement: an updated guideline for reporting

systematic reviews. Systematic Reviews 2021 Mar 29;10(1):89. doi: 10.1186/s13643-021-01626-4
39. Cane J, Richardson M, Johnston M, Ladha R, Michie S. From lists of behaviour change techniques (BCTs) to structured hierarchies: comparison of two methods of developing a hierarchy of BCTs. Brit J Health Psych 2015 Feb;20(1):130–150. doi: 10.1111/bjhp.12102
40. Cumpston M, Li T, Page MJ, Chandler J, Welch VA, Higgins JP, Thomas J. Updated guidance for trusted systematic reviews: a new edition of the Cochrane Handbook for Systematic Reviews of Interventions. Cochrane Db Syst Rev 2019 Oct 3;10(10):ED000142. PMID:31643080
41. Christopoulou SC, Kotsilieris T, Anagnostopoulos I. Assessment of Health Information Technology Interventions in Evidence-Based Medicine: A Systematic Review by Adopting a Methodological Evaluation Framework. Healthcare (Basel, Switzerland) 2018 Aug 31;6(3):109. PMID:30200307
42. Lin L, Zhang J, Hodges JS, Chu H. Performing Arm-Based Network Meta-Analysis in R with the pcnetmeta Package. J Stat Softw 2017 Aug;80:5. doi: 10.18637/jss.v080.i05
43. Xu C, Niu Y, Wu J, Gu H, Zhang C. Software and package applicating for network meta-analysis: A usage-based comparative study. Journal of Evidence-Based Medicine 2018 Aug;11(3):176–183. PMID:29266878
44. Bhatnagar N, Lakshmi PVM, Jeyashree K. Multiple treatment and indirect treatment comparisons: An overview of network meta-analysis. Perspectives in Clinical Research 2014 Oct;5(4):154–158. PMID:25276624
45. Shim S, Yoon B-H, Shin I-S, Bae J-M. Network meta-analysis: application and practice using Stata. Epidemiology and Health 2017;39:e2017047. PMID:29092392
46. Spineli LM. An empirical comparison of Bayesian modelling strategies for missing binary outcome data in network meta-analysis. BMC medical research methodology 2019 Apr 24;19(1):86. doi: 10.1186/s12874-019-0731-y
47. Sedgwick P, Marston L. How to read a funnel plot in a meta-analysis. BMJ (Clinical research ed) 2015 Sep 16;351:h4718. PMID:26377337
48. Begg CB, Mazumdar M. Operating characteristics of a rank correlation test for publication bias. Biometrics 1994 Dec;50(4):1088–1101.
49. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ (Clinical research ed) 1997 Sep 13;315(7109):629–634. PMID:9310563
50. Glasgow RE, Toobert DJ. Brief, computer-assisted diabetes dietary self-management counseling: effects on behavior, physiologic outcomes, and quality of life. Med Care 2000 Nov;38(11):1062–1073. doi: 10.1097/00005650-200011000-00002
51. Keyserling TC, Samuel-Hodge CD, Ammerman AS, Ainsworth BE, Henríquez-Roldán CF, Elasy TA, Skelly AH, Johnston LF, Bangdiwala SI. A Randomized Trial of an Intervention to Improve Self-Care Behaviors of African-American Women With Type 2 Diabetes: Impact on physical activity. Diabetes Care 2002 Sep 1;25(9):1576–1583. doi: 10.2337/diacare.25.9.1576
52. Tate DF, Jackvony EH, Wing RR. Effects of Internet Behavioral Counseling on Weight Loss in Adults at Risk for Type 2 Diabetes: A Randomized Trial. Jama 2003 Apr 9;289(14):1833–1836. doi: 10.1001/jama.289.14.1833
53. Young RJ, Taylor J, Friede T, Hollis S, Mason JM, Lee P, Burns E, Long AF, Gambling T, New JP, Gibson JM. Pro-Active Call Center Treatment Support (PACCTS) to Improve Glucose Control in Type 2 Diabetes: A randomized controlled trial. Diabetes Care 2005 Feb 1;28(2):278–282. doi: 10.2337/diacare.28.2.278
54. Kim H-S, Jeong H-S. A nurse short message service by cellular phone in type-2 diabetic patients for six months. J Clin Nurs 2007;16(6):1082–1087. doi: 10.1111/j.1365-2702.2007.01698.x
55. Lorig K, Ritter PL, Villa F, Piette JD. Spanish Diabetes Self-Management With and Without Automated Telephone Reinforcement: Two randomized trials. Diabetes Care 2008 Mar 1;31(3):408–414. doi: 10.2337/dc07-1313
56. Quinn CC, Clough SS, Minor JM, Lender D, Okafor MC, Gruber-Baldini A. WellDoc™

Mobile Diabetes Management Randomized Controlled Trial: Change in Clinical and Behavioral Outcomes and Patient and Physician Satisfaction. Diabetes Technol The 2008 Jun;10(3):160–168. doi: 10.1089/dia.2008.0283
57. Powers BJ, Olsen MK, Oddone EZ, Bosworth HB. The Effect of a Hypertension Self-Management Intervention on Diabetes and Cholesterol Control. Am J Med 2009 Jul 1;122(7):639–646. doi: 10.1016/j.amjmed.2008.12.022
58. Nelson LA, Greevy RA, Spieker A, Wallston KA, Elasy TA, Kripalani S, Gentry C, Bergner EM, LeStourgeon LM, Williamson SE, Mayberry LS. Effects of a Tailored Text Messaging Intervention Among Diverse Adults With Type 2 Diabetes: Evidence From the 15-Month REACH Randomized Controlled Trial. Diabetes Care 2021 Jan;44(1):26–34. doi: 10.2337/dc20-0961
59. Feng Y, Zhao Y, Mao L, Gu M, Yuan H, Lu J, Zhang Q, Zhao Q, Li X. The Effectiveness of an eHealth Family-Based Intervention Program in Patients With Uncontrolled Type 2 Diabetes Mellitus (T2DM) in the Community Via WeChat: Randomized Controlled Trial. JMIR mHealth and uHealth 2023 Mar 20;11:e40420. doi: 10.2196/40420
60. Ruissen MM, Torres-Peña JD, Uitbeijerse BS, Arenas de Larriva AP, Huisman SD, Namli T, Salzsieder E, Vogt L, Ploessnig M, van der Putte B, Merle A, Serra G, Rodríguez G, de Graaf AA, de Koning EJP, Delgado-Lista J, Sont JK. Clinical impact of an integrated e-health system for diabetes self-management support and shared decision making (POWER2DM): a randomised controlled trial. Diabetologia 2023;66(12):2213–2225. doi: 10.1007/s00125-023-06006-2
61. Mansberger SL, Gleitsmann K, Gardiner S, Sheppler C, Demirel S, Wooten K, Becker TM. Comparing the Effectiveness of Telemedicine and Traditional Surveillance in Providing Diabetic Retinopathy Screening Examinations: A Randomized Controlled Trial. Telemedicine Journal and e-Health 2013 Dec;19(12):942–948. PMID:24102102
62. Young HM, Miyamoto S, Dharmar M, Tang-Feldman Y. Nurse Coaching and Mobile Health Compared With Usual Care to Improve Diabetes Self-Efficacy for Persons With Type 2 Diabetes: Randomized Controlled Trial. JMIR mHealth and uHealth 2020 Mar 2;8(3):e16665. doi: 10.2196/16665
63. Hansel B, Giral P, Gambotti L, Lafourcade A, Peres G, Filipecki C, Kadouch D, Hartemann A, Oppert J-M, Bruckert E, Marre M, Bruneel A, Duchene E, Roussel R. A Fully Automated Web-Based Program Improves Lifestyle Habits and HbA1c in Patients With Type 2 Diabetes and Abdominal Obesity: Randomized Trial of Patient E-Coaching Nutritional Support (The ANODE Study). J Med Internet Res 2017 Nov 8;19(11):e360. doi: 10.2196/jmir.7947
64. Weymann N, Dirmaier J, von Wolff A, Kriston L, Härter M. Effectiveness of a Web-Based Tailored Interactive Health Communication Application for Patients With Type 2 Diabetes or Chronic Low Back Pain: Randomized Controlled Trial. J Med Internet Res 2015 Mar 3;17(3):e53. doi: 10.2196/jmir.3904
65. Schillinger D, Handley M, Wang F, Hammer H. Effects of Self-Management Support on Structure, Process, and Outcomes Among Vulnerable Patients With Diabetes. Diabetes Care 2009 Apr;32(4):559–566. doi: 10.2337/dc08-0787
66. Davis RM, Hitch AD, Salaam MM, Herman WH, Zimmer-Galler IE, Mayer-Davis EJ. TeleHealth improves diabetes self-management in an underserved community: diabetes TeleCare. Diabetes Care 2010 Aug;33(8):1712–1717. doi: 10.2337/dc09-1919
67. Glasgow RE, Christiansen SM, Kurz D, King DK, Woolley T, Faber AJ, Estabrooks PA, Strycker L, Toobert D, Dickman J. Engagement in a diabetes self-management website: usage patterns and generalizability of program use. J Med Internet Res 2011 Jan 25;13(1):e9. doi: 10.2196/jmir.1391
68. Wild SH, Hanley J, Lewis SC, McKnight JA, McCloughan LB, Padfield PL, Parker RA, Paterson M, Pinnock H, Sheikh A, McKinstry B. Supported Telemonitoring and Glycemic Control in People with Type 2 Diabetes: The Telescot Diabetes Pragmatic Multicenter Randomized Controlled Trial. PLoS medicine 2016 Jul;13(7):e1002098. doi: 10.1371/journal.pmed.1002098

69. Crowley MJ, Tarkington PE, Bosworth HB, Jeffreys AS, Coffman CJ, Maciejewski ML, Steinhauser K, Smith VA, Dar MS, Fredrickson SK, Mundy AC, Strawbridge EM, Marcano TJ, Overby DL, Majette Elliott NT, Danus S, Edelman D. Effect of a Comprehensive Telehealth Intervention vs Telemonitoring and Care Coordination in Patients With Persistently Poor Type 2 Diabetes Control: A Randomized Clinical Trial. JAMA internal medicine 2022 Sep 1;182(9):943–952. doi: 10.1001/jamainternmed.2022.2947
70. Hesseldal L, Christensen JR, Olesen TB, Olsen MH, Jakobsen PR, Laursen DH, Lauridsen JT, Nielsen JB, Søndergaard J, Brandt CJ. Long-term Weight Loss in a Primary Care-Anchored eHealth Lifestyle Coaching Program: Randomized Controlled Trial. J Med Internet Res 2022 Sep 23;24(9):e39741. doi: 10.2196/39741
71. Lavikainen P, Mattila E, Absetz P, Harjumaa M, Lindström J, Järvelä-Reijonen E, Aittola K, Männikkö R, Tilles-Tirkkonen T, Lintu N, Lakka T, van Gils M, Pihlajamäki J, Martikainen J. Digitally Supported Lifestyle Intervention to Prevent Type 2 Diabetes Through Healthy Habits: Secondary Analysis of Long-Term User Engagement Trajectories in a Randomized Controlled Trial. J Med Internet Res 2022 Feb 24;24(2):e31530. doi: 10.2196/31530
72. Nagata T, Aoyagi S-S, Takahashi M, Nagata M, Mori K. Effects of Feedback From Self-Monitoring Devices on Lifestyle Changes in Workers with Diabetes: 3-Month Randomized Controlled Pilot Trial. JMIR formative research 2022 Aug 9;6(8):e23261. PMID:35943766
73. Thorsen IK, Yang Y, Valentiner LS, Glümer C, Karstoft K, Brønd JC, Nielsen RO, Brøns C, Christensen R, Nielsen JS, Vaag AA, Pedersen BK, Langberg H, Ried-Larsen M. The Effects of a Lifestyle Intervention Supported by the InterWalk Smartphone App on Increasing Physical Activity Among Persons With Type 2 Diabetes: Parallel-Group, Randomized Trial. JMIR mHealth and uHealth 2022 Sep 28;10(9):e30602. doi: 10.2196/30602
74. Yin W, Liu Y, Hu H, Sun J, Liu Y, Wang Z. Telemedicine management of type 2 diabetes mellitus in obese and overweight young and middle-aged patients during COVID-19 outbreak: A single-center, prospective, randomized control study. PloS One 2022;17(9):e0275251. PMID:36174028
75. Calikoglu F, Bagdemir E, Celik S, Idiz C, Ozsarı H, Issever H, Satman I. Telemedicine as a Motivational Tool to Optimize Metabolic Control in Patients with Diabetes in Turkey: A Prospective, Randomized, Controlled TeleDiab Trial. Telemedicine and e-Health 2023 Apr;29(4):518–530. doi: 10.1089/tmj.2022.0028
76. Cheung NW, Redfern J, Thiagalingam A, Hng T-M, Marschner S, Haider R, Faruquie S, Von Huben A, She S, McIntyre D, Cho J-G, Chow CK, SupportMe Investigators. Effect of Mobile Phone Text Messaging Self-Management Support for Patients With Diabetes or Coronary Heart Disease in a Chronic Disease Management Program (SupportMe) on Blood Pressure: Pragmatic Randomized Controlled Trial. J Med Internet Res 2023 Jun 16;25:e38275. doi: 10.2196/38275
77. Gerber BS, Biggers A, Tilton JJ, Smith Marsh DE, Lane R, Mihailescu D, Lee J, Sharp LK. Mobile Health Intervention in Patients With Type 2 Diabetes: A Randomized Clinical Trial. JAMA network open 2023 Sep 5;6(9):e2333629. doi: 10.1001/jamanetworkopen.2023.33629
78. Han C-Y, Zhang J, Ye X-M, Lu J-P, Jin H-Y, Xu W-W, Wang P, Zhang M. Telemedicine-assisted structured self-monitoring of blood glucose in management of T2DM results of a randomized clinical trial. BMC medical informatics and decision making 2023 Sep 14;23(1):182. doi: 10.1186/s12911-023-02283-4
79. Nelson LA, Spieker AJ, Greevy RA, Roddy MK, LeStourgeon LM, Bergner EM, El-Rifai M, Aikens JE, Wolever RQ, Elasy TA, Mayberry LS. Glycemic outcomes of a family-focused intervention for adults with type 2 diabetes: Main, mediated, and subgroup effects from the FAMS 2.0 RCT. Diabetes Res Clin Pract 2023 Dec;206:110991. doi: 10.1016/j.diabres.2023.110991
80. Whitehouse CR, Knowles M, Long JA, Mitra N, Volpp KG, Xu C, Sabini C, Gerald N, Estrada I, Jones D, Kangovi S. Digital Health and Community Health Worker Support for Diabetes Management: a Randomized Controlled Trial. J Gen Intern Med 2023 Jan;38(1):131–137. doi:

10.1007/s11606-022-07639-6
81. Zamanillo-Campos R, Fiol-deRoque MA, Serrano-Ripoll MJ, Mira-Martínez S, Ricci-Cabello I. Development and evaluation of DiabeText, a personalized mHealth intervention to support medication adherence and lifestyle change behaviour in patients with type 2 diabetes in Spain: A mixed-methods phase II pragmatic randomized controlled clinical trial. Int J Med Inf 2023 Aug;176:105103. doi: 10.1016/j.ijmedinf.2023.105103
82. Lee DY, Yoo S-H, Min KP, Park C-Y. Effect of Voluntary Participation on Mobile Health Care in Diabetes Management: Randomized Controlled Open-Label Trial. JMIR mHealth and uHealth 2020 Sep 18;8(9):e19153. doi: 10.2196/19153
83. Bender MS, Cooper BA, Park LG, Padash S, Arai S. A Feasible and Efficacious Mobile-Phone Based Lifestyle Intervention for Filipino Americans with Type 2 Diabetes: Randomized Controlled Trial. JMIR diabetes 2017 Dec 12;2(2):e30. PMID:30291068
84. Fortmann AL, Gallo LC, Garcia MI, Taleb M, Euyoque JA, Clark T, Skidmore J, Ruiz M, Dharkar-Surber S, Schultz J, Philis-Tsimikas A. Dulce Digital: An mHealth SMS-Based Intervention Improves Glycemic Control in Hispanics With Type 2 Diabetes. Diabetes Care 2017 Oct;40(10):1349–1355. doi: 10.2337/dc17-0230
85. Lee JY, Wong CP, Tan CSS, Nasir NH, Lee SWH. Telemonitoring in fasting individuals with Type 2 Diabetes Mellitus during Ramadan: A prospective, randomised controlled study. Sci Rep 2017 Aug 31;7(1):10119. PMID:28860546
86. Quinn CC, Swasey KK, Crabbe JCF, Shardell MD, Terrin ML, Barr EA, Gruber-Baldini AL. The Impact of a Mobile Diabetes Health Intervention on Diabetes Distress and Depression Among Adults: Secondary Analysis of a Cluster Randomized Controlled Trial. JMIR mHealth and uHealth 2017 Dec 7;5(12):e183. doi: 10.2196/mhealth.8910
87. Ramadas A, Chan CKY, Oldenburg B, Hussein Z, Quek KF. Randomised-controlled trial of a web-based dietary intervention for patients with type 2 diabetes: changes in health cognitions and glycemic control. BMC public health 2018 Jun 8;18(1):716. doi: 10.1186/s12889-018-5640-1
88. Sarayani A, Mashayekhi M, Nosrati M, Jahangard-Rafsanjani Z, Javadi M, Saadat N, Najafi S, Gholami K. Efficacy of a telephone-based intervention among patients with type-2 diabetes; a randomized controlled trial in pharmacy practice. Int J Clin Pharm-net 2018 Apr;40(2):345–353. doi: 10.1007/s11096-018-0593-0
89. Torbjørnsen A, Småstuen MC, Jenum AK, Årsand E, Ribu L. Acceptability of an mHealth App Intervention for Persons With Type 2 Diabetes and its Associations With Initial Self-Management: Randomized Controlled Trial. JMIR mHealth and uHealth 2018 May 21;6(5):e125. doi: 10.2196/mhealth.8824
90. Agarwal P, Mukerji G, Desveaux L, Ivers NM, Bhattacharyya O, Hensel JM, Shaw J, Bouck Z, Jamieson T, Onabajo N, Cooper M, Marani H, Jeffs L, Bhatia RS. Mobile App for Improved Self-Management of Type 2 Diabetes: Multicenter Pragmatic Randomized Controlled Trial. JMIR mHealth and uHealth 2019 Jan 10;7(1):e10321. doi: 10.2196/10321
91. Höchsmann C, Infanger D, Klenk C, Königstein K, Walz SP, Schmidt-Trucksäss A. Effectiveness of a Behavior Change Technique-Based Smartphone Game to Improve Intrinsic Motivation and Physical Activity Adherence in Patients With Type 2 Diabetes: Randomized Controlled Trial. JMIR serious games 2019 Feb 13;7(1):e11444. doi: 10.2196/11444
92. MacPherson MM, Merry KJ, Locke SR, Jung ME. Effects of Mobile Health Prompts on Self-Monitoring and Exercise Behaviors Following a Diabetes Prevention Program: Secondary Analysis From a Randomized Controlled Trial. JMIR mHealth and uHealth 2019 Sep 5;7(9):e12956. doi: 10.2196/12956
93. Sun C, Sun L, Xi S, Zhang H, Wang H, Feng Y, Deng Y, Wang H, Xiao X, Wang G, Gao Y, Wang G. Mobile Phone-Based Telemedicine Practice in Older Chinese Patients with Type 2 Diabetes Mellitus: Randomized Controlled Trial. JMIR mHealth and uHealth 2019 Jan 4;7(1):e10664. doi: 10.2196/10664

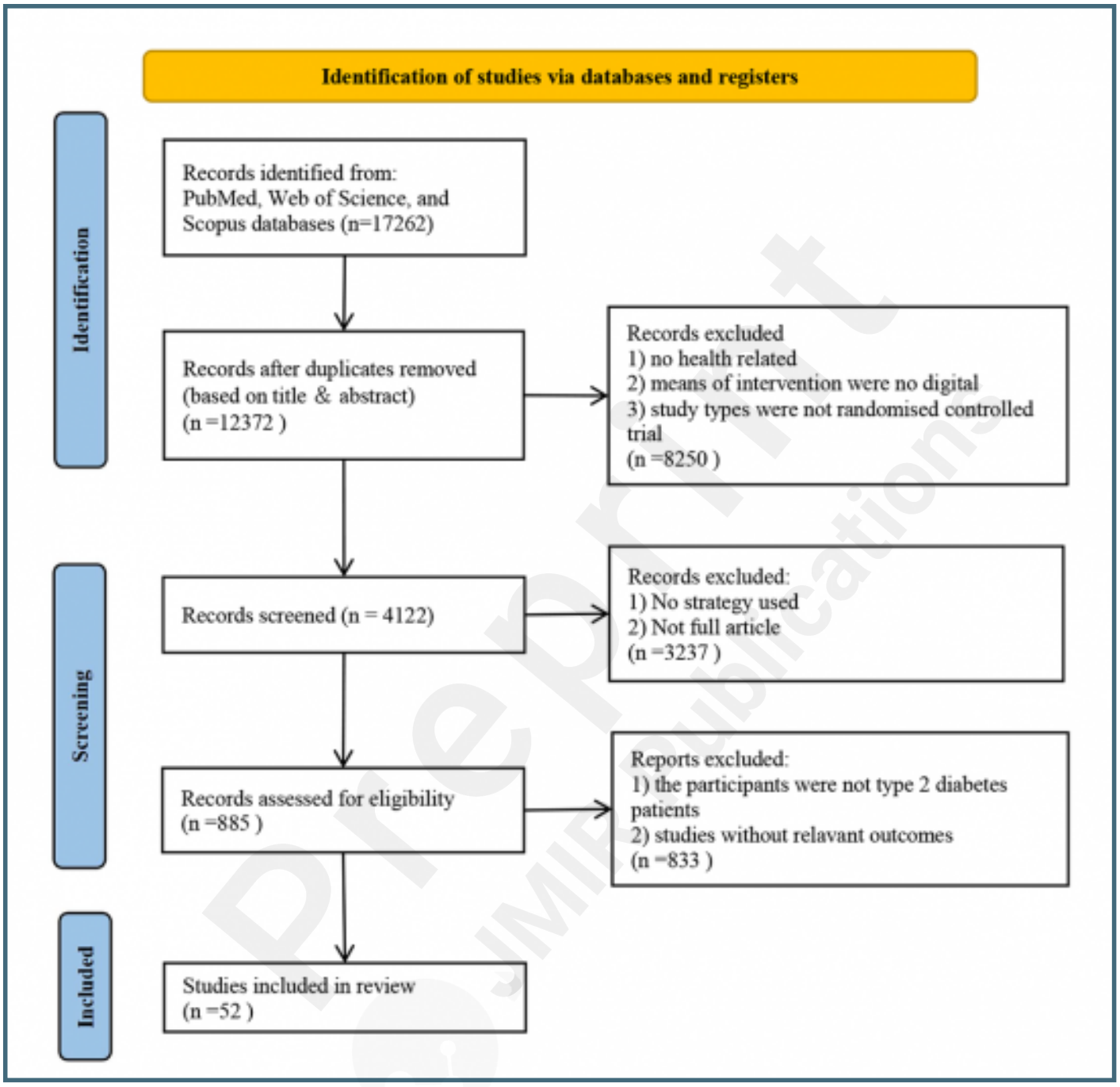
94. Torbjørnsen A, Jenum AK, Småstuen MC, Arsand E, Holmen H, Wahl AK, Ribu L. A Low-Intensity Mobile Health Intervention With and Without Health Counseling for Persons With Type 2 Diabetes, Part 1: Baseline and Short-Term Results From a Randomized Controlled Trial in the Norwegian Part of RENEWING HEALTH. JMIR mHealth and uHealth 2014 Dec 11;2(4):e52. doi: 10.2196/mhealth.3535
95. Vervloet M, van Dijk L, de Bakker DH, Souverein PC, Santen-Reestman J, van Vlijmen B, van Aarle MCW, van der Hoek LS, Bouvy ML. Short- and long-term effects of real-time medication monitoring with short message service (SMS) reminders for missed doses on the refill adherence of people with Type 2 diabetes: evidence from a randomized controlled trial. Diabetic Medicine: A Journal of the British Diabetic Association 2014 Jul;31(7):821–828. PMID:24646343
96. Wakefield BJ, Koopman RJ, Keplinger LE, Bomar M, Bernt B, Johanning JL, Kruse RL, Davis JW, Wakefield DS, Mehr DR. Effect of home telemonitoring on glycemic and blood pressure control in primary care clinic patients with diabetes. Telemedicine Journal and E-Health: The Official Journal of the American Telemedicine Association 2014 Mar;20(3):199–205. PMID:24404819
97. Zhou P, Xu L, Liu X, Huang J, Xu W, Chen W. Web-based telemedicine for management of type 2 diabetes through glucose uploads: a randomized controlled trial. Int J Clin Exp Patho 2014;7(12):8848–8854. PMID:25674254
98. Fukuoka Y, Gay CL, Joiner KL, Vittinghoff E. A Novel Diabetes Prevention Intervention Using a Mobile App: A Randomized Controlled Trial With Overweight Adults at Risk. Am J Prev Med 2015 Aug;49(2):223–237. doi: 10.1016/j.amepre.2015.01.003
99. Greenwood DA, Blozis SA, Young HM, Nesbitt TS, Quinn CC. Overcoming Clinical Inertia: A Randomized Clinical Trial of a Telehealth Remote Monitoring Intervention Using Paired Glucose Testing in Adults With Type 2 Diabetes. J Med Internet Res 2015 Jul 21;17(7):e178. doi: 10.2196/jmir.4112
100. Nicolucci A, Cercone S, Chiriatti A, Muscas F, Gensini G. A Randomized Trial on Home Telemonitoring for the Management of Metabolic and Cardiovascular Risk in Patients with Type 2 Diabetes. Diabetes Technol The 2015 Aug;17(8):563–570. doi: 10.1089/dia.2014.0355
101. Shan R, Sarkar S, Martin SS. Digital health technology and mobile devices for the management of diabetes mellitus: state of the art. Diabetologia 2019 Jun;62(6):877–887. doi: 10.1007/s00125-019-4864-7
102. Dixon RF, Zisser H, Layne JE, Barleen NA, Miller DP, Moloney DP, Majithia AR, Gabbay RA, Riff J. A Virtual Type 2 Diabetes Clinic Using Continuous Glucose Monitoring and Endocrinology Visits. Journal of Diabetes Science and Technology 2020 Sep;14(5):908–911. PMID:31762302
103. Ridho A, Alfian SD, van Boven JFM, Levita J, Yalcin EA, Le L, Alffenaar J-W, Hak E, Abdulah R, Pradipta IS. Digital Health Technologies to Improve Medication Adherence and Treatment Outcomes in Patients With Tuberculosis: Systematic Review of Randomized Controlled Trials. J Med Internet Res 2022 Feb 23;24(2):e33062. doi: 10.2196/33062
104. Moschonis G, Siopis G, Jung J, Eweka E, Willems R, Kwasnicka D, Asare BY-A, Kodithuwakku V, Verhaeghe N, Vedanthan R, Annemans L, Oldenburg B, Manios Y, DigiCare4You Consortium. Effectiveness, reach, uptake, and feasibility of digital health interventions for adults with type 2 diabetes: a systematic review and meta-analysis of randomised controlled trials. The Lancet Digital Health 2023 Mar;5(3):e125–e143. PMID:36828606
105. Kerr D, Edelman S, Vespasiani G, Khunti K. New Digital Health Technologies for Insulin Initiation and Optimization for People With Type 2 Diabetes. Endocrine Practice: Official Journal of the American College of Endocrinology and the American Association of Clinical Endocrinologists 2022 Aug;28(8):811–821. PMID:35452813
106. Gershkowitz BD, Hillert CJ, Crotty BH. Digital Coaching Strategies to Facilitate Behavioral Change in Type 2 Diabetes: A Systematic Review. J Clin Endocrinol Metab 2021 Mar 25;106(4):e1513–e1520. PMID:33206975

107. Roy K, Iqbal S, Gadag V, Bavington B. Relationship Between Psychosocial Factors and Glucose Control in Adults With Type 2 Diabetes. Can J Diabetes 2020 Oct;44(7):636–642. doi: 10.1016/j.jcjd.2020.01.005
108. Alaofè H, Hounkpatin WA, Djrolo F, Ehiri J, Rosales C. Knowledge, attitude, practice and associated factors among patients with type 2 diabetes in Cotonou, Southern Benin. BMC public health 2021 Feb 12;21(1):339. doi: 10.1186/s12889-021-10289-8

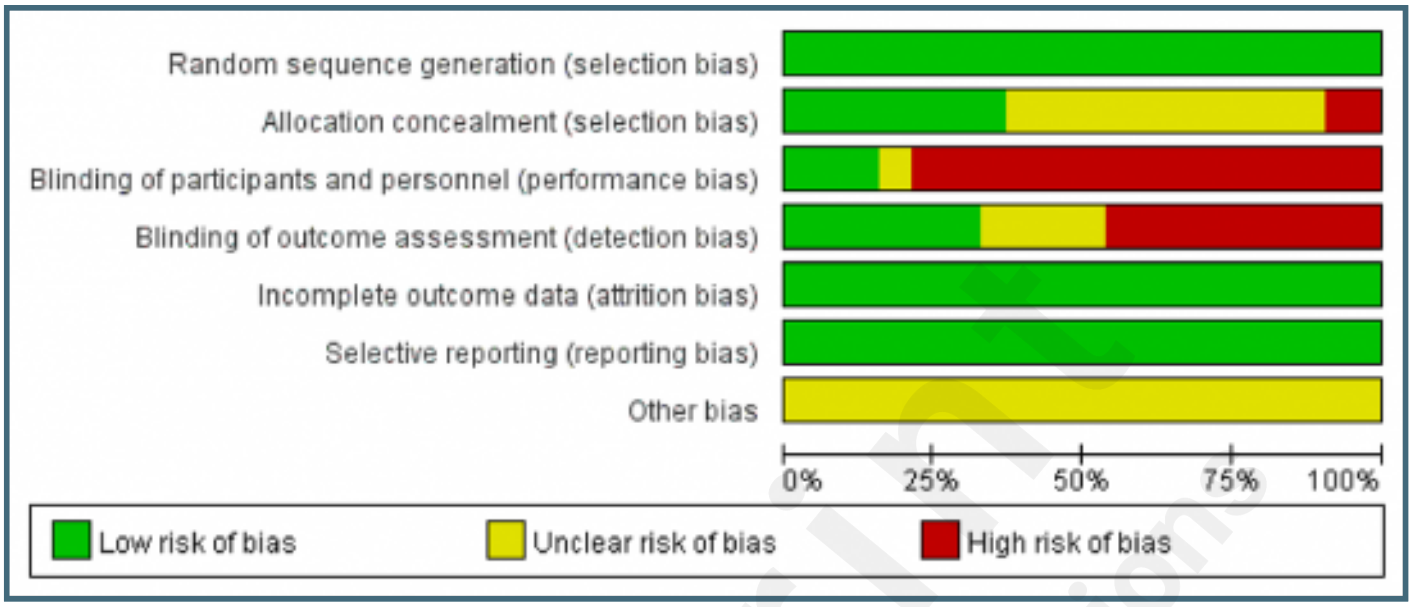
Supplementary Files

Figures

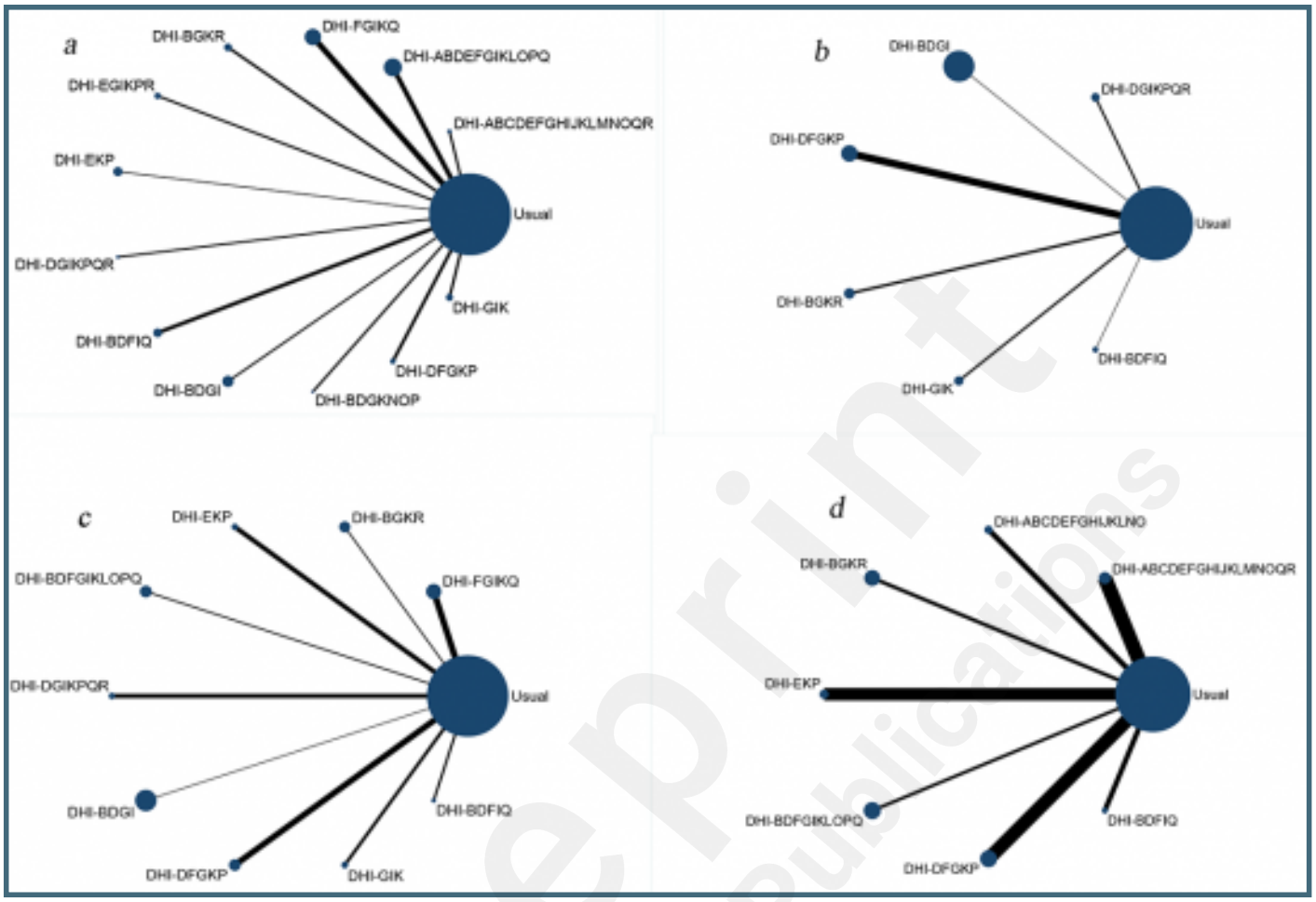
Flow diagram for the search and selection of the included studies.



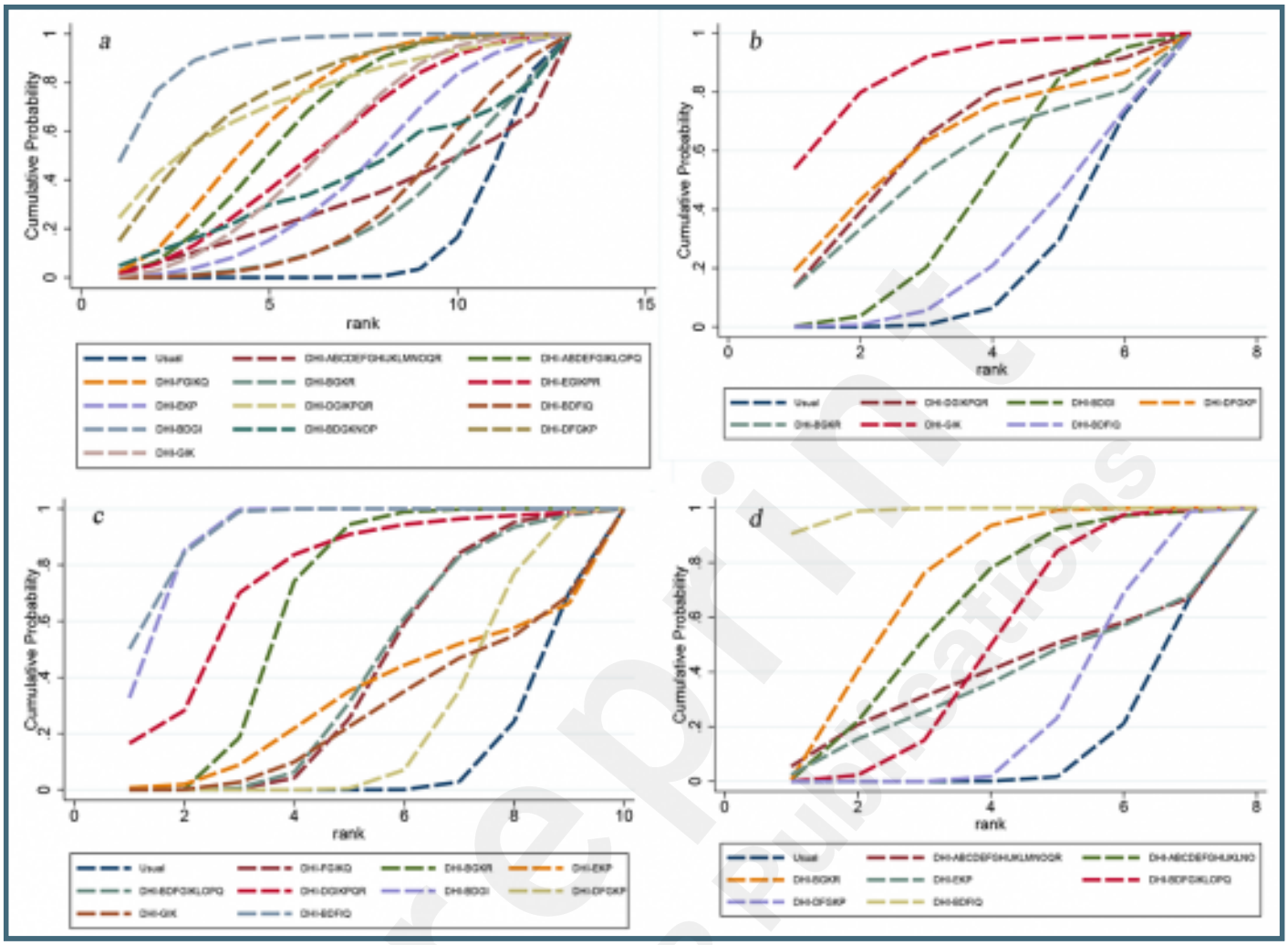
Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.



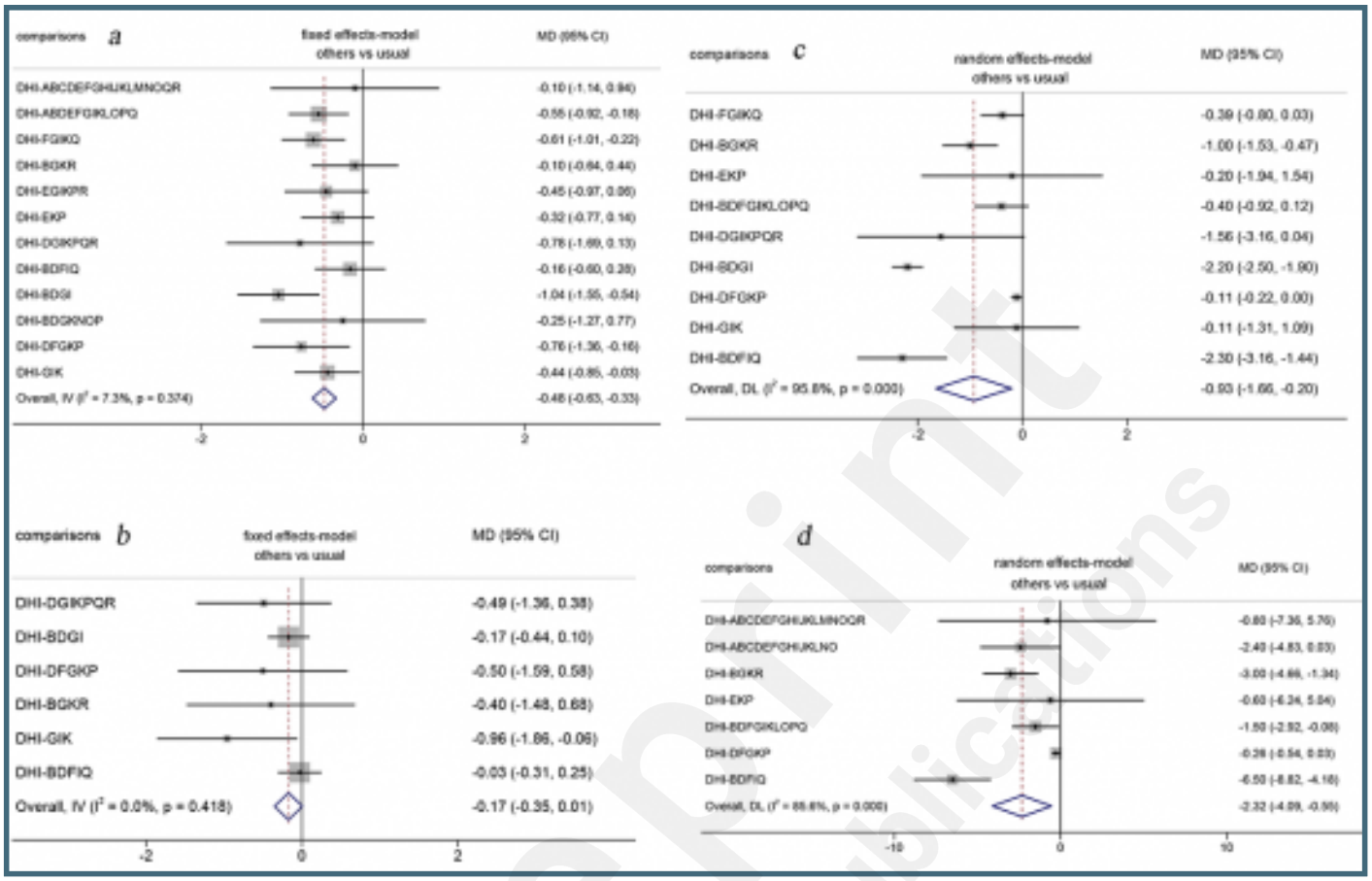
Evidence network of outcome indicators.



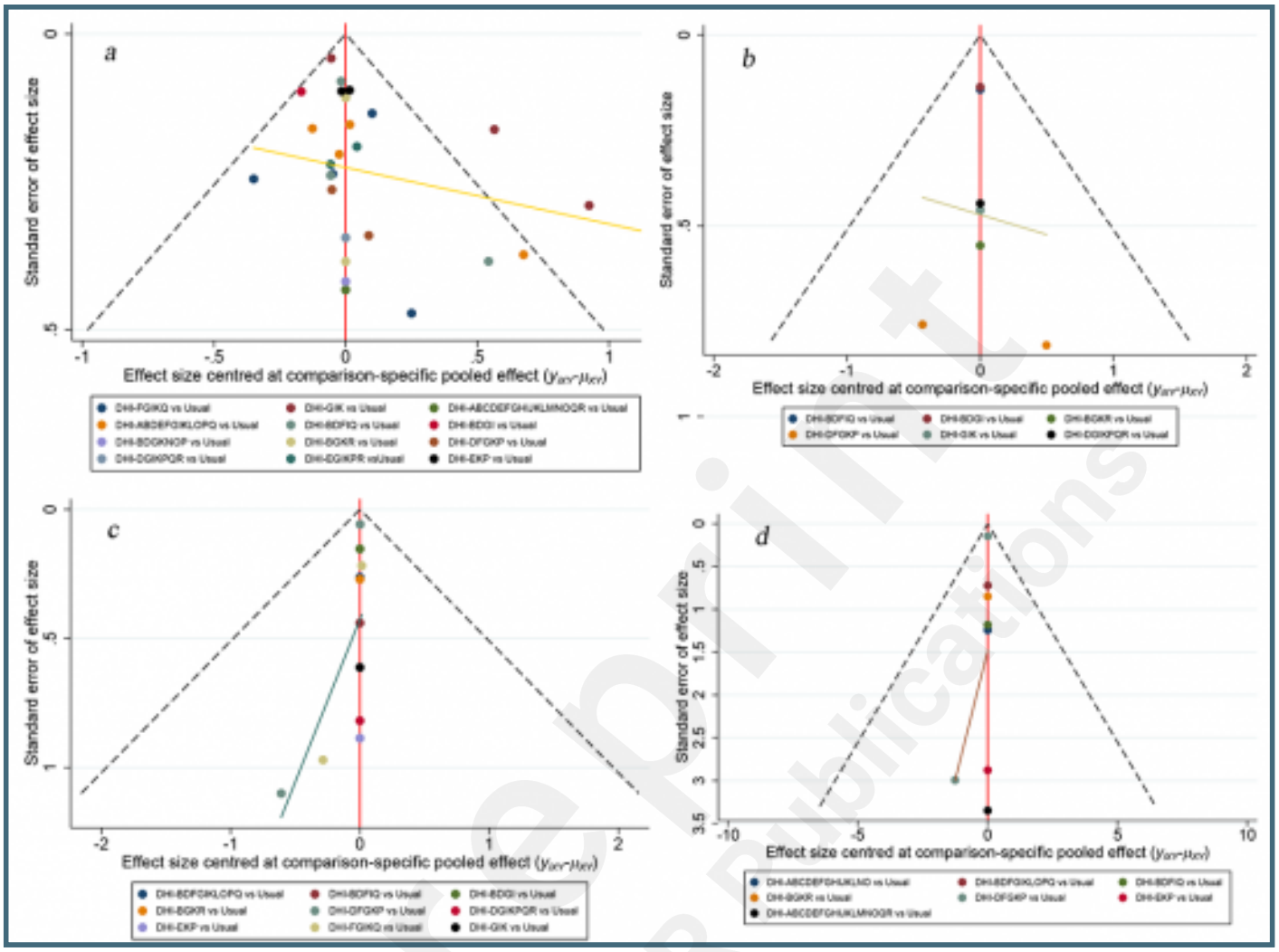
SUCRA rank of outcome indicators.



Forest plots of network meta-analysis results.



Comparison adjusted funnel plots of trials included in the network meta-analysis.



Sensitivity analyses using the method of removing individual studies separately.

Multimedia Appendixes

Search strategy.
URL: http://asset.jmir.pub/assets/10539299199102169893408c1f506f33.docx

Behavior Change Techniques (BCTs).
URL: http://asset.jmir.pub/assets/9bc8a8b875e48cabef0e0dd773b33041.docx

The characteristics of the included studies.
URL: http://asset.jmir.pub/assets/b935dff1af92703874bf43e98f379940.xlsx

The detailed information about strategies and strategy combinations.
URL: http://asset.jmir.pub/assets/d29cc11ff5efd0ee9eaec3c2bb55408b.xlsx

Evaluation of the effectiveness of different digital health intervention strategies based on SF-HIT.
URL: http://asset.jmir.pub/assets/4bf13d62597d862784ffe94e18d8b1bf.xlsx

Risk of bias and quality assessments of included studies.
URL: http://asset.jmir.pub/assets/86e48f24308283820cd44a7e6a215f59.xlsx

Supplementary materials.
URL: http://asset.jmir.pub/assets/e4e6de51b1ed7a114d3a7e1fa03022c0.docx

CONSORT (or other) checklists

PRISMA NMA Checklist.
URL: http://asset.jmir.pub/assets/63b64e9e7562b6a5b7283fdae5038794.pdf