Obesity Reviews

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REVIEW OPEN ACCESS

Effectiveness of Mobile Application-Based Multimodal Behavioral Interventions on Weight Loss in Obesity: A Systematic Review and Meta-Analysis

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Received: 12 August 2025 | **Revised:** 14 July 2026 | **Accepted:** 19 August 2026

Keywords: digital therapy | DTx | lifestyle intervention | meta-analysis | obesity | overweight | public health care

ABSTRACT

Background: Healthcare systems face increasing demands in chronic disease management such as obesity. Mobile applications offer scalable tools for weight management, ranging from simple trackers to prescribable digital therapeutics.

Objective: This review evaluates the effectiveness of fully remote, app-based interventions using a multimodal approach for weight loss in adults with obesity. Complying with international guidelines, these interventions combine behavior change strategies for diet, physical activity, and/or psychosocial education.

Methods: A systematic literature search was performed. Eligible studies were assessed using the Cochrane Risk of Bias Tool 2 and the Grading of Recommendations, Assessment, Development and Evaluation approach for certainty of evidence. A meta-analysis was performed for body weight outcomes.

Results: Twelve randomized controlled trials and five systematic reviews were included, reporting changes in body weight or body mass index. The standardized mean difference of body weight changes at the end of intervention was −0.50 (95% confidence interval: −0.77, −0.22), corresponding to a mean difference of −2.61 kg (−4.45, −0.78). Heterogeneity was substantial ($I^2 = 79.2\%$; $p < 0.0001$).

Conclusion: Fully remote, app-based interventions show moderate weight loss with promising potential in obesity management. However, heterogeneity between studies highlights the need for further research into potential factors with a significant influence on the results.

1 | Introduction

Healthcare systems are experiencing significant pressure due to increasing costs and demands of care in chronic disease management. Obesity is one of the major public health challenges of the 21st century. According to current data from 2022, an estimated 890 million adults and over 160 million children and adolescents worldwide are obese [1]. Treatment of obesity, and the prevention of its comorbidities, such as type 2 diabetes or cardiovascular disease requires long-term management and

Abbreviations: Apps, mobile applications; BMI, body mass index; CG, control group; CI, confidence interval; DiGA, *Digitale Gesundheitsanwendung* (digital health application); DTx, digital therapeutics; GRADE, Grading of Recommendations Assessment Development and Evaluation; HCP, healthcare professional; HR, heart rate; IG, intervention group; ITT, intention-to-treat; LOCF, last observation carried forward; MD, mean difference; PICOS, population, intervention, control, outcome study design; PP, per-protocol; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RCT, randomized controlled trial; SD, standard deviation; SMD, standardized mean difference; SMS, short message service; WHO, World Health Organization.

resources that further strain systems that are often designed for acute care [2, 3].

The treatment goal is clinically meaningful and sustainable weight loss, thereby reducing comorbidity risks [3, 4]. Treatment should also aim for enhanced quality of life, mental well-being, and improved physical and social functioning [3]. As first-line treatment, international clinical guidelines on obesity treatment recommend multimodal lifestyle-based therapy including dietary counseling, promotion of physical activity, and training in psychosocial wellbeing such as the handling of stress or (self-) stigma. A holistic approach should incorporate multiple behavior change techniques, delivered by features such as educational content, self-monitoring, goal-setting, feedback, and social support [3–6].

Increasingly, these multimodal therapies are being delivered through various digital tools like smartphone or web applications, short message service (SMS) messages, wearables, and personal digital assistants [6–10]. Previous research has shown a moderate effect on weight loss that is comparable or even more effective than conventional in-person programs [8], with smartphones being the most effective subgroup [7].

Particularly mobile applications (apps) have emerged as promising tools in weight management that can help to overcome disparities in healthcare access in terms of location and time. Apps include a variety of technologies such as simple diet or fitness trackers to prescribable digital therapeutics (DTx). They allow flexible and interactive behavioral intervention, which can enhance adherence and patient engagement [10].

DTx is paving its way into national public healthcare systems. In Germany, reimbursable DTx, so-called digital health applications (DiGAs), are available and more countries are about to establish similar programs [11, 12]. DiGAs are medical devices that are highly government-regulated, based on scientific research and proven to be safe and effective via clinical studies. The inclusion of DiGAs in the German national guideline for obesity treatment further highlights their significance [13].

While previous systematic reviews have focused on various digital media (SMS, wearables, browser-based, etc.), including interventions with parallel on-site counseling or often evaluated unimodal interventions (e.g., focusing solely on nutrition or physical activity), this review particularly aims to evaluate the effectiveness of fully remote, app-based interventions for weight loss in adults with obesity. All included interventions were delivered via smartphone applications with any additional support, such as counseling or feedback, provided exclusively through digital and remote channels. In addition, the focus of this study was on interventions that followed a multimodal design, defined as the combination of at least two behavioral change modules (nutrition, physical activity, and/or psychosocial education) and thereby complying with international guidelines [3, 4]. We conducted a systematic review and meta-analysis of randomized controlled trials (RCTs) to assess their impact on body weight and discuss the potential benefit and limitations of such DTx in public health care systems.

2 | Materials and Methods

2.1 | Search Strategy and Eligibility Criteria

A systematic literature search was conducted in the databases PubMed, Cochrane Library, Nature, PubPsych, and IEEE Xplore in February 2025, with the aim to search for evidence related to mobile health lifestyle interventions for weight loss in a patient population with obesity. Studies that also included participants with overweight were only eligible if the reported mean body mass index (BMI) of the study population was $\geq 30\,\text{kg/m}^2$. The search strategy followed the Population, Intervention, Control, Outcome, Study Design (PICOS) framework and included a combination of search terms, Medical Subject Headings and Boolean operators. The search terms were tailored to each database to account for database-specific indexing structures and search capabilities. The detailed search strategy is presented in Tables S1–S5. Studies were eligible if they met the inclusion criteria (Table 1) and were published in English or German language between 2014 and 2025.

2.2 | Study Selection and Data Extraction

Search results were imported into zotero (Version 6.0.37), and duplicates were identified and removed by the citation management software. The title and abstract screening as well as the full text screening were completed independently by two reviewers using CADIMA, a web-based tool to support systematic reviews in environmental and health sciences (Version 2.2.4.2) [14]. Full texts were retrieved for all eligible records. Discrepancies were resolved through discussion and consensus, involving a third reviewer, if necessary. The reference lists of relevant identified systematic reviews were manually screened for potential cross references that met the inclusion criteria.

Data were extracted independently by two reviewers using a standardized data extraction sheet developed for this review. Extracted variables included study characteristics (author, year, title, country, study design, and sample size), participant characteristics (age, sex, and baseline BMI), intervention details (duration, follow-up, modality, and intervention components), comparator details (type of control group), outcomes (primary: change in body weight, reported in kg, %, or BMI units; secondary: quality of life and cardiovascular parameters), time points of outcome measurement, and safety reports (e.g., adverse events). For weight-related outcomes, both postintervention results (excluding follow-up) and outcomes assessed at 6 months were extracted where available.

2.3 | Outcomes

The primary outcome was the change in a body weight measure from baseline to postintervention, reported as absolute (kg) or percentage (%) changes in body weight or BMI (kg/m^2). Where available, weight loss data reported at the 6-month follow-up was also extracted. To be included in the meta-analysis, RCTs had to report mean values at baseline and follow-up with corresponding standard deviations (SDs) or 95% confidence intervals (CIs) or the mean change with SDs or CIs. Studies reporting

TABLE 1 | Eligibility criteria for RCTs according to PICOS.

	Inclusion	Exclusion
Population	Adult patients with obesity or studies where the sample mean BMI was ≥ 30 kg/m^2 (even if participants with overweight were eligible)	Age < 18 years, pregnancy, sample mean BMI < 30 kg/m^2, population limited to special social or ethnic subgroups (e.g., low income)
Intervention	Digital multimodal lifestyle intervention being delivered via mobile apps and including at least two treatment modules (nutrition, physical activity, and/or psychosocial education). If personal support was included, it must be delivered remotely (e.g., text message or phone call)	Mobile app not part of the intervention, unimodal interventions focused on only one treatment module, personal support delivered on site, weight loss medication, bariatric surgery
Control	Standard of care, wait-list control, little to no intervention (e.g., leaflet)	Control group that included app component or that received comparator intervention (e.g., on site intervention)
Outcome	Body weight (in kg, %, or BMI change). Secondary outcomes of interest: quality of life, cardiovascular endpoints (if available)	Body weight or BMI not reported
Study design	RCTs, systematic reviews, meta-analyses	Other study designs not meeting the inclusion criteria

Abbreviations: BMI, body mass index; PICOS, Population, Intervention, Control, Outcome, Study design; RCT, randomized controlled trial.

insufficient data were excluded from the meta-analysis but considered for qualitative synthesis if other eligibility criteria were met.

A meta-analysis was performed for the primary outcome of interest, weight change at the end of the intervention using the standardized mean difference (SMD). In addition, to provide insights about the absolute weight change, a meta-analysis using the mean difference (MD) was performed including only studies reporting absolute weight changes (kg). One study just reported % weight change, but the original data in kg were available from the authors [15]. For the 6-month timepoint, meta-analyses for SMD and MD were also conducted.

Secondary outcomes of interest included quality of life (e.g., validated questionnaires) and cardiovascular measures (e.g., blood pressure) and were extracted if available. Secondary outcomes were reported narratively.

2.4 | Statistical Analysis

All statistical analyses were performed using R (Version 4.4.2) within the RStudio environment. Prior to conducting the meta-analysis, if studies did not report SDs, these were calculated from reported CIs or, where available, baseline and follow-up SDs, using established methods.

Random-effects models were applied, accounting for between-study heterogeneity in estimated effects, using the "meta::metacont" function of the R "meta" package (Version 8.0-2). The SMD between intervention and control groups was calculated using Hedges' g, which corrects for small sample bias, as well as the MD. We calculated the SMD and MD between intervention and control groups for two different time points. First, weight change at the end of intervention was analyzed, and second, 6 months data was analyzed if available. To extract the highest quality data, analyses were based on intention-to-treat (ITT) data when available. Otherwise, per-protocol (PP) data were used. For each analysis, the I^2 statistic is reported, which quantifies the observed heterogeneity and is interpreted using conventional thresholds (i.e., 25%: low; 50%: moderate; 75%: substantial).

Sensitivity and outlier analyses were conducted for the primary endpoint—SMD at the end of the intervention. Sensitivity analysis involved excluding studies with a high risk of bias, as determined by the Cochrane RoB 2 Tool [16], and calculating the meta-analysis only with 6 months data, excluding all studies that did not report weight loss results for this timepoint.

2.5 | Risk of Bias and Quality Assessment

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [17]. The corresponding PRISMA checklist is available in Table S6. The review protocol was registered in the PROSPERO database (ID: CRD420250653535).

The risk of bias of the included RCTs was independently assessed by two reviewers using the Cochrane RoB 2 tool [16]. Disagreements were resolved through discussion, consulting a third reviewer if no consensus could be reached.

Potential publication bias was assessed by visual inspection of funnel plots and, where appropriate, using Egger's regression test to detect funnel plot asymmetry. In line with methodological recommendations [18], these analyses were only conducted when at least 10 studies were available for a given outcome to ensure adequate power and reduce the likelihood of spurious results due to small-sample effects. Funnel plots were generated using the "meta::funnel" function from the R "meta" package.

Egger's regression test was calculated using the "eggers.test" function from the "dmetar" package (Version 0.1.0) [19].

To assess the overall certainty of evidence, the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach was applied using the GDT software [20]. These assessments focused on the primary outcome, weight change between groups at the end of intervention.

2.6 | Exploratory Post Hoc Analysis

To identify potential characteristics that differentiated between effect sizes we conducted a subsequent descriptive analysis. Studies were categorized into high or low performers based on the SMD forest plot and we reviewed the individual components of the interventions. For each intervention, we then summed the number of distinct behavior change components (e.g., goal-setting, self-monitoring, and personalized feedback), allowing for a basic quantitative comparison across performance groups. To examine whether this contributed to outcome differences, the number of components was descriptively compared with the observed weight loss effects. This analysis was not part of the initial analysis plan and was conducted *post hoc* following a review of the primary results.

3 | Results

3.1 | Study Selection

The systematic literature search identified a total of 566 records, of which 102 duplicates were removed. The remaining 464 records were screened at title and abstract level, followed by full text screening. One additional record was identified via manual reference screening of eligible systematic reviews.

A total of 17 studies met the inclusion criteria, comprising 12 RCTs and five systematic reviews. Of the RCTs, 10 studies were included in the meta-analysis. One study reported insufficient data [21], another study reported PP analysis for 3-month data [22] of a larger trial [23]. These studies were therefore only included in the narrative synthesis. The detailed study selection process is illustrated in Figure 1.

3.2 | Study Characteristics

The included studies were published between 2014 and 2025 and conducted across various geographical regions worldwide. All studies evaluated app-based multimodal interventions targeting weight loss in an adult patient population with a mean BMI $\geq 30\,\text{kg/m}^2$.

Sample sizes ranged from 50 to 650, with intervention durations between 3 and 24 months. Interventions typically included behavior change techniques such as nutrition counseling, physical activity support, and other lifestyle modification strategies delivered via mobile health apps. Some studies included remote personal interaction of varying intensity as part of the intervention (e.g., SMS messages or structured coaching calls).

Across the included studies, the role of the app varied in terms of intensity, autonomy, and integration within the multimodal intervention. In several studies, the app served as the central element in delivering the full multimodal intervention as a standalone treatment arm. The apps contained various intervention components. The majority of those apps included varying forms of self-monitoring (e.g., tracking of diet and/or physical activity), educational components, and a goal-setting function, for example, [22–24]. Personalized feedback and/or prompts based on user input were also present in most interventions, for example, [15, 25].

In some trials, the app was integrated into a broader blended or remotely supported care model, where the app delivered core content and self-monitoring features, while remote human support was offered asynchronously or sporadically [26, 27], via remotely delivered structured personal contact [28, 29] or by including peer or social support [21, 30, 31]. A detailed overview of the implementation of different features is broken down in Table S7.

All studies reported results immediately after intervention; a subset also provided data at the 6-month timepoint and some also included postintervention follow-up. Further details on study characteristics of the included RCTs are presented in Table 2.

3.3 | Risk of Bias and Quality Assessment

The risk of bias was evaluated using the Cochrane RoB 2 tool [16]. Among the 10 RCTs included in the primary meta-analysis, one was rated as low risk, six as some concerns, and three as high risk of bias. Detailed judgments per domain are visualized in Figure 2.

Heterogeneity was assessed using I^2 statistics, which indicated substantial heterogeneity across the included studies for the primary analysis, SMD between studies at the end of intervention timepoint ($I^2 = 79.2\%$) and for the between-study MD at the end of intervention ($I^2 = 85.6\%$).

Potential publication bias was assessed by visual inspection of funnel plots and, where appropriate, using Egger's regression test to detect funnel plot asymmetry. These analyses were conducted for the primary outcome of weight change, specifically for the SMD and MD at the end of intervention timepoint as these analyses included at least 10 studies.

Visual inspection of the funnel plot for the SMD showed no indication for publication bias. The plot for the MD revealed some potential for asymmetry, with fewer studies in the bottom left region. However, in both plots, the scatter of data points was generally in line with the funnel boundaries and there was no pronounced asymmetry (Figures S1 and S2). It is also important to note that the small number of included studies can make the visual interpretation of funnel plots challenging, as observed variation can also occur by chance [18].

To quantify the funnel plot asymmetry with Egger's regression test, the intercept and its associated p value were recorded. p values > 0.05 for both SMD and MD, respectively, indicated no

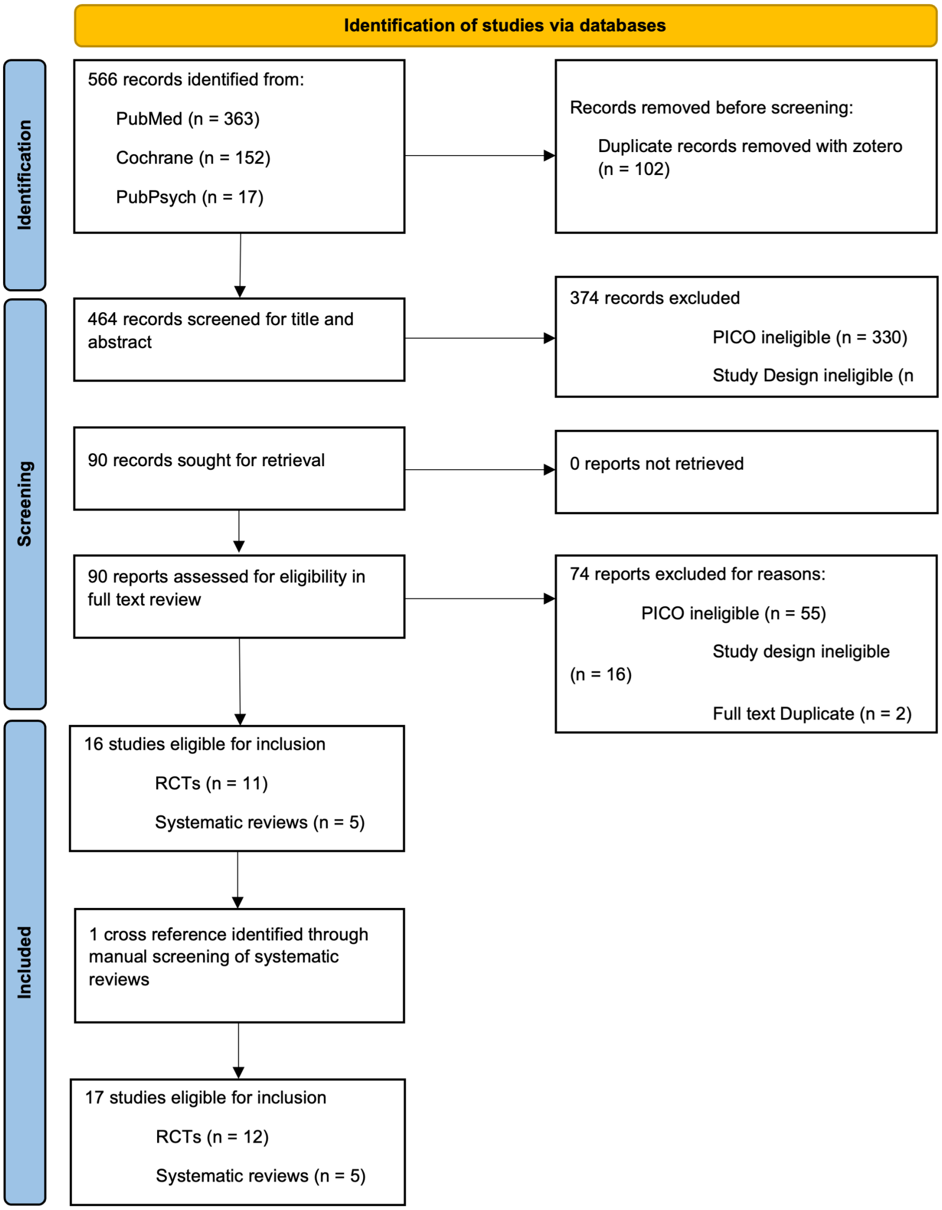

FIGURE 1 | Flowchart of the study selection process adapted from PRISMA (2020) statement (Page et al.). Systematic reviews were manually screened and eligible studies were included as cross references. PICO, Population, Intervention, Control, Outcome; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RCT, randomized controlled trial.

statistically significant asymmetry and, therefore, no potential publication bias (Table S8).

The investigations described above all contributed to evaluate the overall certainty of evidence according to the GRADE approach, with the summary of findings summarized in Table 3. The quality of evidence for the primary outcome, weight change between groups at the end of intervention, was rated as moderate, downgraded due to inconsistency. Some of the included RCTs had a high risk of bias, mainly due to potential selective reporting. However, sensitivity analysis excluding these studies did not significantly alter the main findings, suggesting that the overall result is robust (Table S9). Therefore, no downgrade for risk of bias was applied. Certainty of evidence for secondary outcomes was not assessed due to lack of data availability and consistency.

3.4 | Weight Loss Results

3.4.1 | Results From Systematic Reviews

This review identified five systematic reviews consistently reporting an association between smartphone-based interventions and weight loss. A meta-analysis by Cavero-Redondo et al. (2020) reported a moderate effect of mobile health interventions incorporating self-monitoring on weight loss ($n = 20$; SMD $= -0.37$; MD $= -1.78$), with smartphone-based approaches demonstrating superior effectiveness [7]. Patel et al. (2021) systematically reviewed 39 studies on digital self-monitoring in behavioral weight loss interventions among adults with overweight or obesity and found a consistent association with weight loss, with websites and mobile apps being the most common modalities [8]. Wang et al. (2020) reviewed

TABLE 2 | Study characteristics.

Study	Country	Sample size	Participants	Mean BMI at baseline[a]	Intervention	Duration
Lugones-Sanchez et al. (2020, 2022)[b]	Spain	650	Age 20–65 years BMI 27.5–40 kg/m^2 Classified as sedentary	33.0 kg/m^2	EVIDENT 3 app + smartband (Xiaomi Miband 2)	3-month intervention 12-month follow-up
Roth et al. (2023)	Germany	149	Age 18–65 years BMI 30–40 kg/m^2	35.8 kg/m^2	zanadio app	12-month intervention
Simpson et al. (2020)	Scotland	109	Age 18–70 years BMI $\geq$ 30 kg/m^2	37.6 kg/m^2	HelpMeDoIt! App + website	12-month intervention
Gemesi et al. (2024)	Germany	168	Age 18–70 years BMI 30–40 kg/m^2	34.2 kg/m^2	Oviva Direkt app	3-month intervention 6-month follow-up
Apiñaniz et al. (2019)	Spain	110	Age 18–45 years BMI $\geq$ 25 kg/m^2	32.7 kg/m^2	AKTIDIET app	6-month intervention
Hurkmans et al. (2018)	Belgium	102	Age 18–65 years BMI 29–34 kg/m^2	32.0 kg/m^2	mHealth app (developed by BrandNewHealth) + Facebook group	3-month intervention
Ruiz-Leon et al. (2025)[d]	Spain	123	Age 18–75 Recent diagnosis of type 2 diabetes	31.8 kg/m^2 [c]	Greenhabit app + HCP calls + optional social support feature	3-month intervention
Svetkey et al. (2015)	USA	365	Age 18–35 years BMI $\geq$ 25 kg/m^2	35.2 kg/m^2	Smartphone app (designed by investigator) + buddy support	24-month intervention
Hesseldal et al. (2022)	Denmark	338	Age 18–70 years BMI 30–45 kg/m^2	35.3 kg/m^2	LIVA app + asynchronous digital coaching	6-month intervention 12-month follow-up
Bughin et al. (2021)	France	50	Age 25–65 years BMI $\geq$ 30 kg/m^2	36.2 kg/m^2 [d]	TR Telemouv app + pedometer (Care Trackfit) + HR monitor +2 remote HCP consultations	3-month intervention
Hartman et al. (2016)[d]	USA	54	Women at elevated breast cancer risk BMI $\geq$ 27.5 kg/m^2	31.9 kg/m^2	MyFitnessPal, FitBit, coaching calls	6-month intervention

Abbreviations: App, mobile application; BMI, body mass index; HCP, healthcare professional.
[a]Baseline BMI of total sample.
[b]Reporting preliminary results (Lugones-Sanchez et al. 2020) and complete study (Lugones-Sanchez et al. 2022) of the same sample. Information was extracted from the final publication (Lugones-Sanchez et al. 2022).
[c]Baseline BMI of intervention group used, because baseline BMI of total sample was not reported in the publication.
[d]Other indication and overweight/obesity; baseline mean BMI $\geq$ 30 and reporting weight loss results after a digital multimodal lifestyle intervention involving a smartphone as a central component fulfilled.

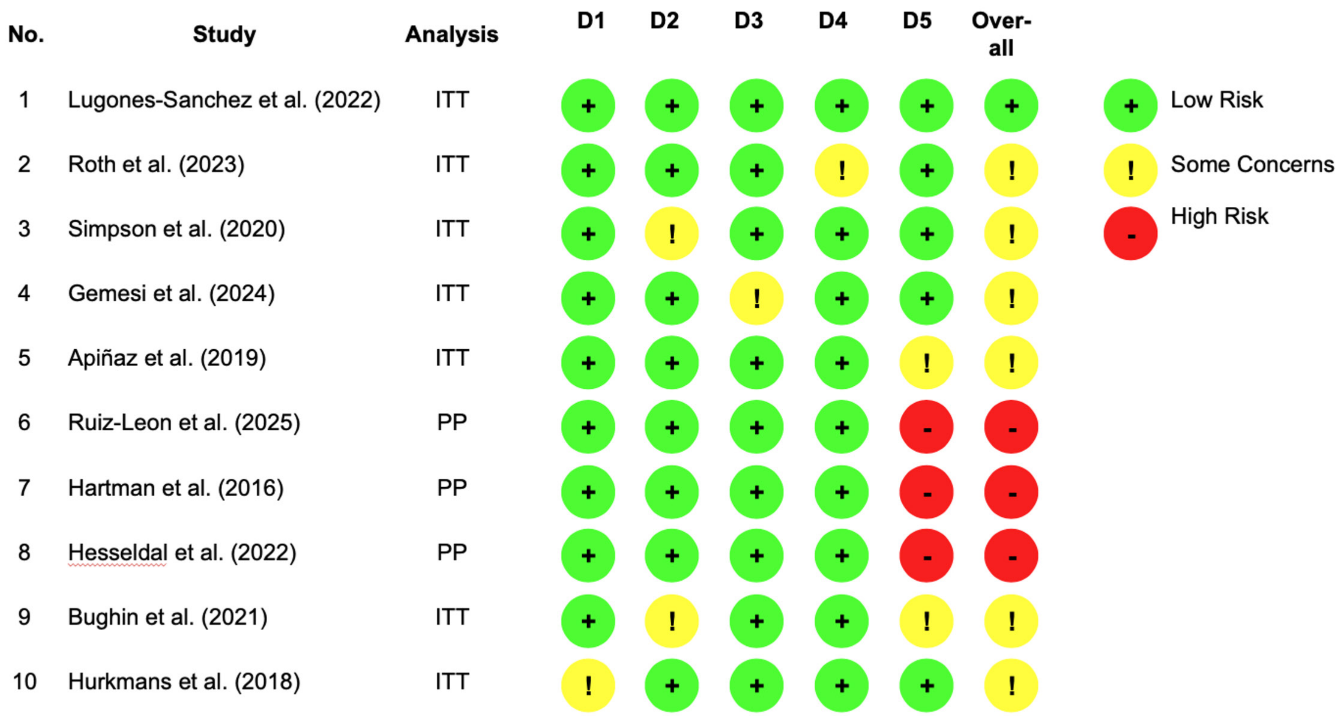

FIGURE 2 | Traffic light plot summarizing the risk of bias rating. D1, randomization process; D2, deviations from the intended interventions; D3, missing outcome data; D4, measurement of the outcome; D5, selection of the reported result. D, domain; ITT, intention-to-treat; PP, per-protocol.

12 studies and concluded that apps and wearables are effective tools for self-regulation in weight management, particularly in primary care strategies [6]. Rumbo-Rodriguez et al. (2020) evaluated 47 technology-based interventions and found that nearly half (47%) achieved significant weight loss, especially those incorporating self-monitoring features [10]. Cheatham et al. (2018) analyzed wearable activity tracking devices used within comprehensive weight loss programs ($n = 25$) and found that such devices may be more effective than standard weight loss programs in the short-term (≤ 6 months), particularly in middle-aged and older adults [9].

3.4.2 | Meta-Analysis

All included RCTs reported weight loss at the end of intervention. However, the intervention duration varied among the studies, ranging from 3 to 12 months. While most studies ($n = 10$) reported weight loss in kg, one study reported it as a percentage [15] and another as BMI reduction [31]. For the meta-analysis, one study was excluded due to insufficient data [21] and another study was excluded because it reported per-protocol analysis for 3-month data (end of intervention) [22], while a subsequent publication of the larger trial reported ITT analysis for the same time point [23]. The meta-analysis of the 6-month timepoint is reported in Figures S3 and S4.

Consequently, the meta-analysis for the primary outcome of weight change at the end of intervention included 10 studies (Figure 3). The pooled between-group SMD in body weight change showed a statistically significant and moderate effect size favoring the intervention group (SMD = −0.50; 95% CI: −0.77 to −0.22; $p < 0.01$). Substantial heterogeneity was observed across the studies ($I^2 = 79.2\%$; $p < 0.01$). The prediction interval was estimated to be (−1.29, 0.30). No outliers were detected.

A sensitivity analysis of the primary meta-analysis was conducted by removing studies with a high risk of bias (per Cochrane RoB 2, specifically those studies reporting PP rather than ITT results) with seven studies remaining. In addition, it was investigated if a fixed observation period of 6 months after beginning of the intervention would yield a more homogeneous result by conducting a meta-analysis on the SMD with 6 months data only (four studies remaining). While the sensitivity analysis excluding high risk of bias studies remained statistically significant (SMD −0.42, 95% CI −0.78, −0.22; $p = 0.0287$), the 6-month analysis showed a strong descriptive trend favoring the intervention group but did not reach statistical significance (SMD −0.58; 95% CI −1.23, 0.08; $p = 0.0684$). This is likely due to the limited number of remaining trials. Compared to the main analysis with an SMD of −0.50 (−0.77; −0.22), the sensitivity analysis excluding the high risk of bias studies produced a slightly smaller effect size of SMD = −0.42 (−0.78, 0.22) and the 6-month analysis a slightly better result with an SMD = −0.58 (−1.23, 0.08). Overall, the direction of the main effect remained consistent across the sensitivity analyses. However, heterogeneity remained significant and wider CIs appeared due to the lower number of studies (Table S9).

In order to provide insights into the absolute weight change of fully app-based, multimodal interventions, a MD analysis was conducted with eight studies reporting absolute changes in body weight (kg) and unpublished results for weight loss in kg were available for one study [15]. Therefore, a separate meta-analysis was conducted on these nine studies, calculating the pooled between-group mean difference at the end of intervention timepoint (Figure 4). The results significantly

TABLE 3 | GRADE certainty of evidence and summary of findings.

Certainty assessment						№ of patients		Effect size		
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	IG (*n*)	CG (*n*)	95% CI	Certainty	Importance
Weight loss SMD end of intervention										
10	RCTs	Not serious[a]	serious[b]	Not serious	Not serious	869	769	SMD **−0.50** (−0.77 to −0.22)	⊕⊕⊕○ Moderate[a,b]	Critical[c]
Weight loss MD end of intervention										
9	RCTs	Not serious[a]	serious[b]	Not serious	Not serious	839	747	MD (kg) **−2.61** (−4.06 to −0.78)	⊕⊕⊕○ Moderate[a,b]	Critical[c]

Note: The "Other factors" column was not included, as no relevant additional considerations were identified during the certainty assessment.
Abbreviations: CG, control group; CI, confidence interval; EOI, end of intervention; GRADE, Grading of Recommendations Assessment, Development and Evaluation; IG, intervention group; MD, mean difference; RCT, randomized controlled trial; SMD, standardized mean difference.
[a]The Cochrane RoB 2 assessment revealed that a considerable proportion of the included RCTs were rated as having a high risk of bias or some concerns. A key source of bias across the evidence base was domain five, which could indicate selective reporting. However, sensitivity analysis excluding these high risk-of-bias studies showed no significant difference to the main analysis, indicating that the overall result is robust.
[b]Substantial heterogeneity was observed.
[c]Weight loss is the primary goal of obesity treatment and is considered critical as it is associated with significant improvements in health and reduction in the risk of sometimes serious comorbidities, for example, cardiovascular disease, which is of high relevance to patients and clinicians.

favored the intervention group (MD = −2.61 kg; 95% CI: −4.45 to −0.78; $p < 0.01$). Again, significant heterogeneity was observed ($I^2 = 85.6\%$; $p < 0.0001$). The prediction interval was estimated to be (−7.73, 2.51).

3.4.3 | Post Hoc Descriptive Findings: Performance Differences and Intervention Characteristics

A visual inspection of the forest plot of the SMD (Figure 3) suggested a potential grouping of studies into those demonstrating more substantial weight loss ("high performers") and those with less pronounced weight loss ("low performers"). This visual shift led to the presumption that this might be related to the interventions' characteristics, prompting a deeper investigation to identify potential explanatory factors for this noticeable difference between the observed outcomes. Specifically, the assumption was that better performance could be attributed to a higher number of components (i.e., features used to deliver behavior change techniques) delivered by the interventions. Supporting information can be found in Table S7.

A small trend may suggest that high-performing interventions [15, 25, 26, 28, 31] include a greater number of behavior change components (mean = 5.0, median = 5.0, range = [4; 6]), compared to low-performing interventions (mean = 4.4, median = 4.0 range = [3; 7]).

3.4.4 | Secondary Outcomes

Secondary outcomes included quality of life and cardiovascular parameters. Due to heterogeneous assessment tools and limited reporting, a narrative synthesis was conducted. Quality of life was assessed in five studies, using various questionnaires. While some reported improvements within or between groups [15, 29], others found no significant effects [25–27]. Seven studies reported cardiovascular data. Three provided only baseline characteristics [22, 23, 25], offering insights into the clinical risk profile of patients with obesity [4]. Hypertension was the most frequently reported comorbidity, with systolic blood pressure values at baseline ranging between 118 and 124 mmHg. Four studies reported cardiovascular outcomes at the end of the intervention period. Hurkmans et al. (2018) found significant between-group improvements in multiple cardiovascular risk factors [31] and Ruiz-Leon et al. (2025) observed significant reductions in blood pressure after 3 months [29]. Other studies found no significant between-group differences after 6 [24, 26] or 12 months [26]. Safety outcomes were only reported in two studies, whereby no adverse events related to the intervention were identified [21, 30].

4 | Discussion

4.1 | Key Findings

This systematic review and meta-analysis investigated the effects of fully remote app-based multimodal lifestyle interventions on weight loss in adults with obesity. The pooled analysis revealed a statistically significant moderate standardized effect

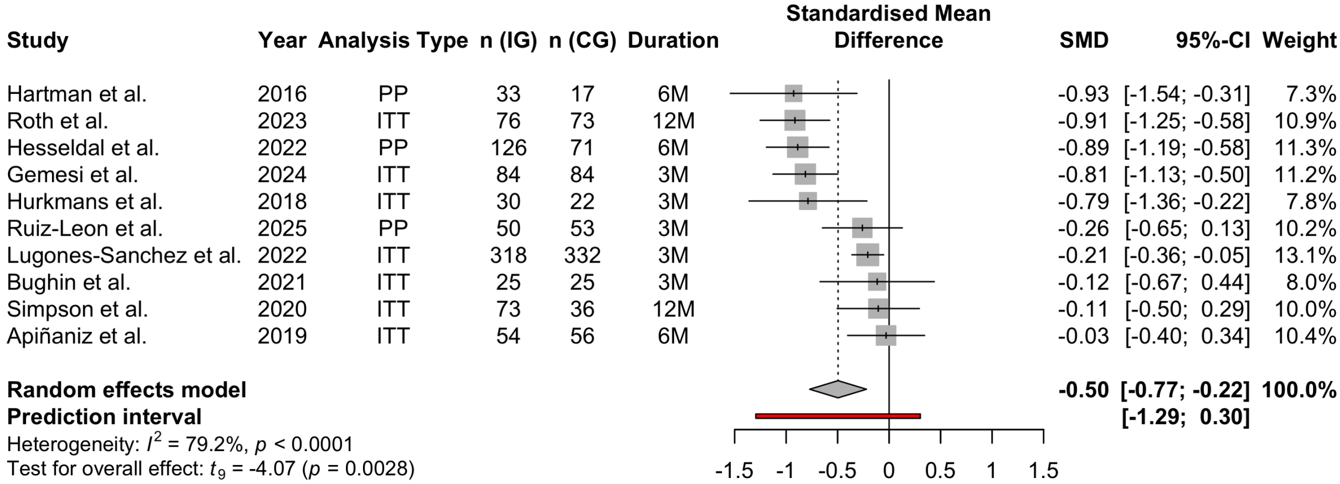

FIGURE 3 | Forest plot of the meta-analysis SMD at the end of intervention. CG, control group; CI, confidence interval; IG, intervention group; ITT, intention-to-treat; PP, per-protocol; SMD, standardized mean difference.

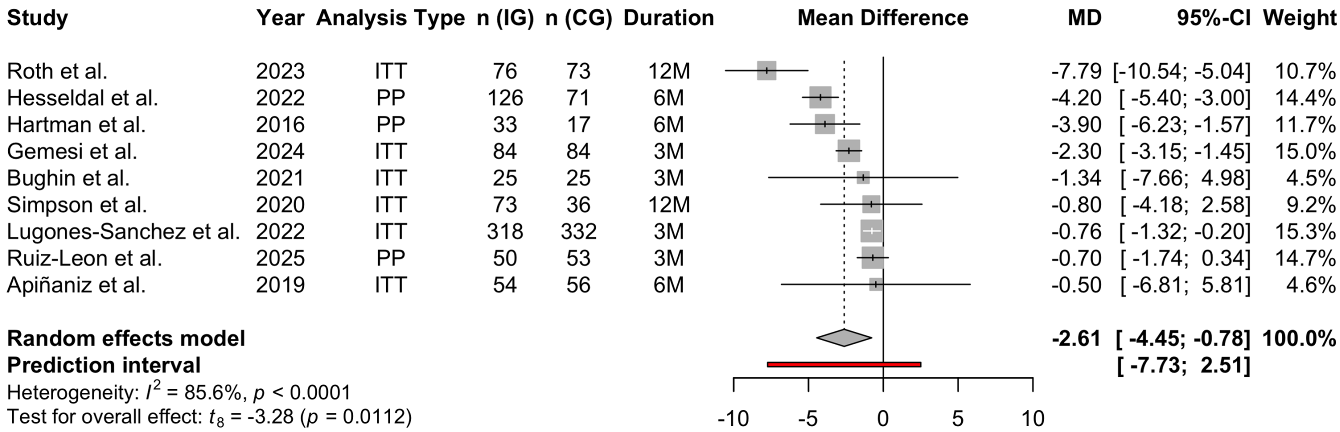

FIGURE 4 | Forest plot of the meta-analysis MD (kg) at the end of intervention. CG, control group; CI, confidence interval; IG, intervention group; ITT, intention-to-treat; PP, per-protocol; MD, mean difference. Data for Roth et al. [15] were available as unpublished absolute weight change in kg.

(SMD) favoring the intervention group. Sensitivity analyses revealed the robustness of the direction of the effect and its significance. However, substantial heterogeneity across studies and wide prediction intervals have been observed, suggesting a strong influence of the intervention, clinical setting or other unexplained differences on the results and likely future study outcomes. Notably, study results either showed a strong effect size ($-0.93 \leq \text{SMD} \leq -0.79$) or a small to very small effect size ($-0.26 \leq \text{SMD} \leq -0.03$). In this work, some of these potentially influential factors have been investigated. However, further research on these factors or their combined effects is needed in order to design optimal behavioral weight loss interventions that can be integrated as digital programs into public health care systems.

The overall mean weight reduction was 2.61 kg, which is consistent with findings from previous reviews of digital health interventions for weight management, which have also reported modest but significant weight loss outcomes [7, 32]. Recent meta-analyses further support these findings, reporting smaller but significant body weight reductions. Lee and Park (2026) isolated the effect of fully automated or one-to-many digital lifestyle interventions targeting diet or physical activity (SMD 0.26, $n = 19$ RCTs) [33], while Puija et al. (2025) focused on smartphone-only interventions for uncomplicated overweight and obesity, demonstrating a modest weight reduction at 4–6 months (SMD −0.33, $n = 8$ RCTs) [34]. In contrast, our analysis focused specifically on weight loss in a population with obesity after multimodal, app-based interventions that allowed remote human interaction. These factors might have contributed to the descriptively more pronounced effect (SMD −0.50).

While previous digital health syntheses are frequently constrained by the inclusion of hybrid formats involving parallel face-to-face coaching, our and recent data collectively confirm that fully remote app-based interventions can drive meaningful behavioral modification. However, the calculated prediction intervals in our analysis, which align with the wide real-world dispersion indices reported by Lee and Park (2026), imply that the expected clinical success in future implementations remains context-dependent and varies across diverse settings. Even with modest weight reductions, long-term cost savings could be achieved through reduced medication use and hospital admissions, especially among individuals with higher BMI or comorbidities [35]. While the mean weight reduction was modest, effective digital programs may offer a scalable and cost-efficient strategy.

In addition to differences in the effectiveness of the various interventions across all studies, between-subject variability with respect to response to intervention is well established [36, 37]. Some of the studies reported a substantial proportion of participants accomplishing at least the 5% weight loss recommendation [15, 23, 26, 31] and high responders achieving 10% weight loss or more [15], underscoring the clinical relevance of fully remote app-based interventions. However, more data are needed to optimize the integration of digital therapeutics into clinical real-world settings and thereby improve the cost-efficiency ratio in obesity treatment. In that regard, companion apps for combined behavioral and pharmacological treatment are gaining interest with the increasing popularity of obesity drugs, in particular GLP-1 RA-based medication [38].

Two of the interventions included in this analysis are certified as regulated digital health applications in Germany and integrated into the healthcare structure [15, 25]. These stand-alone, app-based programs must demonstrate clinical effectiveness, guideline adherence, medical quality, and usability to receive approval. Despite being fully remote without personal interaction, both interventions achieved significant weight loss outcomes of −7.8% after 12 months [15] and −3.2% after 3 months, with sustained effects after 6 months [25]. This suggests that although previous research has shown that human support enhances weight loss outcomes in digital interventions [39], well-designed and scientifically sound digital features may mimic some of these benefits and can lead to clinically meaningful outcomes.

Weight loss of at least 5% is a frequently recommended treatment goal for improving obesity-related complications [4, 40]. Beyond weight loss, a successfully implemented lifestyle intervention can improve cardio-metabolic health outcomes and reduce the risk of developing and progressing obesity-related comorbidities [41–43]. A limited number of studies assessed quality of life and cardiovascular parameters. While some studies indicated improvements, especially in blood pressure or specific quality of life domains, overall evidence remains limited. The heterogeneity in measurement and reporting as well as the small number of studies reporting them precludes drawing general conclusions about the effects of app-based interventions on these secondary outcomes.

4.2 | Possible Explanations for Heterogeneity of Study Results

The substantial heterogeneity observed across studies likely stems from differences in intervention intensity, duration, and methodological quality. However, sensitivity analyses, including the exclusion of studies with high risk of bias due to selective reporting, did not reduce heterogeneity. Similarly, while intervention durations ranged from 3 to 24 months and may have influenced outcomes, heterogeneity persisted even when limiting the analysis to the four studies reporting 6-month weight loss data.

Visual inspection of the SMD forest plot (Figure 3) suggests two clusters: studies with substantial weight loss effects and those with (very) small effect sizes. We explored the number of app features as a potential explanatory factor for this pattern. All interventions targeted diet and physical activity but varied widely in app features and implementation of behavior change techniques. Some provided only self-monitoring and basic education, while others included more comprehensive elements such as goal-setting, personalized feedback, or psychosocial education. Aligning with Bardus et al. (2016), higher-performing studies tended to include more features (mean: 5) compared to low performers (mean: 4.4) [44]. However, this trend was not consistent and limited by the post hoc nature of the analysis. Therefore, this inspection should be interpreted with caution and primarily serves as hypothesis-generating observation for future research.

Overall, none of the exploratory analyses fully explained the heterogeneity or performance differences, suggesting that further research is required. Potentially combined factors are relevant for overall outcome. Alternatively, other factors contributed to the difference in performance. Not just the number, but also the quality, integration and user engagement of behavior change components may determine intervention success. Future studies should systematically assess these qualitative aspects and provide standardized reporting on intervention content and delivery.

4.3 | Strengths and Limitations

This systematic review and meta-analysis has several strengths. It is the first meta-analysis focusing on mobile application–based multimodal behavioral interventions. We followed a rigorous methodology, including a comprehensive search strategy across five databases, independent reviews, and data extraction by two reviewers, minimizing the risk of bias in the review process. The assessment of risk of bias and quality of evidence was conducted using well-established tools (Cochrane RoB 2 and GRADE methodology). Furthermore, the review protocol was prospectively registered in the PROSPERO database, which enhanced transparency and reduced the potential for reporting bias. The inclusion of both RCTs and systematic reviews representing the highest standards of evidence strengthens the validity of our findings. Additionally, our post hoc analysis represents an initial attempt to explore the potential impact of specific intervention characteristics, such as the number of behavior change components, on intervention effectiveness. This exploratory analysis provides a foundation for future research to build upon.

The review also has some limitations, some of which are inherent in the available literature. First, a proportion of the included RCTs were rated as having a high risk of bias, mainly due to potential issues with selective reporting. However, sensitivity analyses demonstrated that excluding these studies did not substantially alter the results. Second, our meta-analysis exhibits substantial heterogeneity across the included studies. This heterogeneity could be attributed to variations in participant or intervention characteristics, such as varying feature sets or different intervention durations, which ranged from three to 12 months in the primary meta-analysis at the end of intervention timepoint. While this heterogeneity is a common challenge in meta-analyses of digital health interventions, reflecting the evolving nature of the field, we addressed it by using random-effects models, which account for such variability. Another limitation is the inconsistent separation of overweight and obesity in many clinical trials. While we included only those studies with a mean BMI $\geq$ 30 kg/m^2 across the study sample, the inclusion of individuals with a BMI between 25 and 30 kg/m^2 might have influenced the observed results due to differing weight loss dynamics. Furthermore, we excluded studies that focused exclusively on specific socio-economic or ethnic subgroups to prioritize interventions designed for the general population. While this limits insights for these specific patient groups, it enhances generalizability to a broader population. It is important to note that these individuals were not categorically excluded; rather, we excluded narrowly tailored trials that did not reflect a general patient base. Lastly, our review has a limited ability to draw conclusions about secondary outcomes such as quality of life and cardiovascular parameters. This was due to the small number of studies reporting on these outcomes and the heterogeneity in how they were measured and reported. One reason for this is that the secondary outcomes were not an inclusion criteria per se but were only extracted from the studies included for weight loss outcomes, if available.

4.4 | Future Implications

Further research is needed to optimize the design and implementation of app-based weight loss interventions for obesity. Given that sustained weight loss is a primary goal of obesity treatment, longitudinal studies investigating the long-term effect of such interventions are needed. To improve weight loss outcomes, future research should focus on determining the most effective combination of intervention components and patient characteristics that may predict individual responses to different approaches. Cost-effectiveness analyses would also be of benefit to inform decisions about resource allocation and the integration of app-based interventions into healthcare systems, including the German DiGA framework. For a comprehensive understanding of digital intervention mechanisms and the optimization of their efficacy, a refined categorization of digital behavior change techniques is essential, alongside a rigorous assessment of their implementation fidelity.

5 | Conclusions

In conclusion, this systematic review and meta-analysis suggests that app-based multimodal lifestyle interventions can lead to significant weight loss in adults with obesity, although substantial heterogeneity between different apps was observed. These findings support the potential of interventions delivered via mobile phones as a scalable and accessible tool for weight management, offering a convenient way to deliver evidence-based interventions and support behavior change. Furthermore, this review provides initial indications regarding potential drivers of intervention effectiveness. Our analysis suggests that incorporating more behavior change components in app-based weight loss interventions may improve their effectiveness, although we cannot yet identify specific components responsible for this effect. Given the significant global health burden of obesity and the increasing recognition of digital health interventions as a key strategy for weight management, future investigations are essential to explore the potential of these intervention components and their combination to maximize the impact of digital health interventions for obesity.

Acknowledgments

Funding for this study was provided by Sidekick Health Germany GmbH. The funder had no role in the study design, data extraction, analysis, interpretation, and manuscript preparation. Open Access funding enabled and organized by Projekt DEAL.

Conflicts of Interest

Emma Bodner, Annika Gentz, and Kathleen Wiencke are employees of the Sidekick Health Germany GmbH. Dr. Nora Mehl is a former employee of the Sidekick Health Germany GmbH and founder of the aidhere GmbH.

Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Table S1:** Search string PubMed. **Table S2:** Search string IEEE Xplore. **Table S3:** Search string Nature. **Table S4:** Search string PubPsych. **Table S5:** Search string Cochrane. **Table S6:** PRISMA checklist. **Table S7:** Intervention characteristics. **Table S8:** Egger's regression test. **Table S9:** Summary table sensitivity analysis. **Figure S1:** Funnel plot indicating publication bias for the primary endpoint and weight loss at the end of the intervention (SMD). SMD, standardized mean difference. **Figure S2:** Funnel plot indicating publication bias for the primary endpoint and weight loss at the end of the intervention (MD). MD, mean difference (kg). **Figure S3:** Forest plot meta-analysis SMD at 6-month timepoint. CG, control group; CI, confidence interval; IG, intervention group; SMD, standardized mean difference. **Figure S4:** Forest plot meta-analysis MD (kg) at 6-month timepoint. CG, control group; CI, confidence interval; IG, intervention group; MD, mean difference.