The effect of digital health interventions on postpartum depression or anxiety: a systematic review and meta-analysis of randomized controlled trials

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OBJECTIVE: This study aimed to examine the effect of digital health interventions compared with treatment as usual on preventing and treating postpartum depression and postpartum anxiety.

DATA SOURCES: Searches were conducted in Ovid MEDLINE, Embase, Scopus, Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, and ClinicalTrials.gov.

STUDY ELIGIBILITY REQUIREMENTS: The systematic review included full-text randomized controlled trials comparing digital health interventions with treatment as usual for preventing or treating postpartum depression and postpartum anxiety.

STUDY APPRAISAL AND SYNTHESIS METHODS: Two authors independently screened all abstracts for eligibility and independently reviewed all potentially eligible full-text articles for inclusion. A third author screened abstracts and full-text articles as needed to determine eligibility in cases of discrepancy. The primary outcome was the score on the first ascertainment of postpartum depression or postpartum anxiety symptoms after the intervention. Secondary outcomes included screening positive for postpartum depression or postpartum anxiety –as defined in the primary study –and loss to follow-up, defined as the proportion of participants who completed the final study assessment compared with the number of initially randomized participants. For continuous outcomes, the Hedges method was used to obtain standardized mean differences when the studies used different psychometric scales, and weighted mean differences were calculated when studies used the same psychometric scales. For categorical outcomes, pooled relative risks were estimated.

RESULTS: Of 921 studies originally identified, 31 randomized controlled trials—corresponding to 5532 participants randomized to digital health intervention and 5492 participants randomized to treatment as usual—were included. Compared with treatment as usual, digital health interventions significantly reduced mean scores ascertaining postpartum depression symptoms (29 studies: standardized mean difference, −0.64 [95% confidence interval, −0.88 to −0.40]; I^2=94.4%) and postpartum anxiety symptoms (17 studies: standardized mean difference, −0.49 [95% confidence interval, −0.72 to −0.25]; I^2=84.6%). In the few studies that assessed screen-positive rates for postpartum depression (n=4) or postpartum anxiety (n=1), there were no significant differences between those randomized to digital health intervention and treatment as usual. Overall, those randomized to digital health intervention had 38% increased risk of not completing the final study assessment compared with those randomized to treatment as usual (pooled relative risk, 1.38 [95% confidence interval, 1.18−1.62]), but those randomized to app-based digital health intervention had similar loss-to-follow-up rates as those randomized to treatment as usual (relative risk, 1.04 [95% confidence interval, 0.91−1.19]).

CONCLUSION: Digital health interventions modestly, but significantly, reduced scores assessing postpartum depression and postpartum anxiety symptoms. More research is needed to identify digital health interventions that effectively prevent or treat postpartum depression and postpartum anxiety but encourage ongoing engagement throughout the study period.

Key words: digital health intervention, internet, perinatal mental health, postpartum anxiety, postpartum depression, smartphone application, text message

Introduction

In the year after childbirth, approximately 15% of women experience postpartum depression (PPD)[1] and 20% experience postpartum anxiety (PPA).[2] Previous studies have demonstrated that interventions using psychoeducation[3] or psychotherapy (cognitive behavioral therapy [CBT],[4] interpersonal therapy [IPT],[5] or mindfulness[6]) effectively prevent and treat PPD and PPA. Unfortunately, <20% of women with PPD or PPA have access to these interventions.[7] The inadequate dissemination of programs shown to improve perinatal mental health has been attributed to the limited number of skilled mental health professionals who can provide psychoeducation or psychotherapy in the perinatal period.[8]

Digital health interventions (DHIs) may help expand access to evidence-based psychoeducation or psychotherapy-based perinatal mental health programs. Although the World Health Organization defines DHIs broadly as "a discrete functionality of digital technology that is applied to achieve health objectives,"[9] DHIs may be defined pragmatically as interventions delivered directly to a patient via the internet, a smartphone application (app), or a text message or Short Message

AJOG at a Glance

Why was this study conducted?

Digital health interventions (DHIs) are increasingly used in postpartum depression (PPD) and postpartum anxiety (PPA) prevention and treatment. Eight randomized controlled trials comparing DHI with treatment as usual for PPD and PPA have been published since the most recent meta-analysis.

Key findings

DHIs effectively but modestly reduce symptoms of PPD and PPA overall, particularly when the DHI provides psychotherapy. Those randomized to DHI had higher risk of loss to follow-up (LTFU) than those randomized to TAU overall, but the rate of LTFU was similar among smartphone applications.

What does this add to what is known?

App-based DHIs providing psychotherapy may be the most effective at improving perinatal psychological outcomes and retaining participant engagement.

Service (SMS) program. DHIs have notable advantages when compared with in-person interventions. First, they are accessible to nearly all who reside in the United States: smartphone ownership rates are nearly universal among reproductive-age patients (95% of individuals aged 18−49 years own a smartphone),[10] and most households (77%)—even low-income (57%)[11] or rural households (72%)[12]—have broadband internet at home.[11,12] Second, DHIs bypass barriers such as lack of childcare or unreliable transportation that have been associated with reduced adherence to in-person postpartum care.[13,14] Lastly, DHIs are inherently scalable: once proven effective, DHIs can be widely disseminated without reducing intervention fidelity.

Previous meta-analyses have suggested that DHIs effectively improve PPD or PPA when compared with treatment as usual (TAU) in randomized controlled trials.[15−18] However, these meta-analyses have limitations: most only included internet-based DHIs,[16−18] and the only meta-analysis that included multiple DHI modalities focused exclusively on the effect of DHIs on PPD[15] despite the significant burden of PPA on perinatal populations. In addition, 9 randomized controlled trials comparing DHIs with TAU have been published since 2021.[19−27] Thus, an updated meta-analysis is warranted. The primary aim of this study is to assess the effect of DHIs compared with TAU on preventing or treating PPD and PPA. Secondary aims included assessing the effect of DHIs compared with TAU on treating PPD and PPA overall and the effect of specific DHI modalities on PPD and PPA prevention or treatment.

Methods

Sources

All written methodologies, including search strategies, used in this systematic review and meta-analysis were created

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A.K.L. has served on a medical advisory board for Pharmacosmos Therapeutics, Inc in 2022 and on a medical advisory board for Shield Therapeutics in 2021.

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This study was registered on the International Prospective Register of Systematic Reviews (registration number 2022 CRD42022321649; date of registration, April 28, 2022).

A status report of this study was presented as a poster entitled, "Effect of digital health interventions on preventing or treating postpartum depression or anxiety: a status report of an ongoing systematic review and meta-analysis of randomized controlled trials" at the 2022 Biennial Conference of the International Marcé Society, London, United Kingdom, September 20−22, 2022.

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according to standards and guidelines for conducting and reporting systematic reviews set forth by PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses),[28] PRESS (Peer Review of Electronic Search Strategies),[29] the Institute of Medicine Standards for Systematic Reviews,[30] and the Cochrane Handbook for Systematic Reviews of Interventions.[31] This study was registered on PROSPERO (International Prospective Register of Systematic Reviews; #CRD42022321649) before data abstraction and exempt from institutional board review because only deidentified data derived from previous publications were included.

A medical librarian (A.H.) searched published literature for records discussing PPD, PPA, or postpartum distress and digital or mobile health interventions in pregnant or postpartum people. The librarian created search strategies using a combination of controlled vocabulary and key words in Ovid MEDLINE (1946−), Embase (1947−), Scopus (1823−), Cochrane Database of Systematic Reviews (CDSR), Cochrane Central Register of Controlled Trials (CENTRAL), and ClinicalTrials.gov (1997−). The search was initially completed in October 2021 and was re-executed in December 2022. Appendix 1 describes reproducible search strategies for each database.

Study selection

Two coauthors (A.K.L. and A.R.W.) independently screened all titles and abstracts before jointly reviewing their individual selection of potentially eligible abstracts. Disagreements on potential eligibility were resolved with discussion with a third author (N.K.A.). A.K.L. and A.R.W. then independently reviewed all full-text articles for inclusion, with N.K.A. determining final eligibility in cases of discrepancy. Review articles, case reports or series, abstracts, articles published in languages other than English, and studies without a comparison group or without outcomes of interest were excluded. Randomized trials comparing any perinatal DHI with TAU, defined as routine care, were included. We also reviewed the bibliographies of included studies to identify additional eligible studies not identified in our search of the literature.

Data abstraction

Two authors (A.K.L. and A.R.W.) independently reviewed eligible articles for data abstraction using a data abstraction tool (Appendix 2). The primary outcome was the score obtained on the first postpartum ascertainment after intervention delivery or randomization of depression or anxiety symptoms using any psychometric scales that screen for PPD or PPA. For the secondary psychological outcomes, only studies that assessed PPD or PPA via the most commonly used psychometric scale for PPD (Edinburgh Postnatal Depression Scale [EPDS][32]) and for PPA (Generalized Anxiety Disorder-7 [GAD-7][33]) were included. Other secondary outcomes included screening positive at any postpartum assessment for depression or anxiety—as defined in the primary study—and loss to follow-up (LTFU), defined as the proportion of participants who completed the final study assessment compared with the number of initially randomized participants.

The same 2 reviewers also assessed the quality of each study using prespecified criteria adapted from the Cochrane Handbook[31] in a system of classification used previously.[34−36] High-quality studies were defined as trials with appropriate randomization methods, clear definitions of primary outcomes, and intention-to-treat analyses. Lower-quality studies were those missing at least 1 of these attributes.[34−36] If a study did not include sufficient data to judge an attribute, that attribute was categorized as missing. Disagreements on study quality classification were resolved by discussion with a third author (N.K.A.).

Data synthesis and assessment of risk of bias

All statistical analyses were performed with the metan package in Stata, version 16.0 (StataCorp LLC, College Station, TX). Heterogeneity between studies was assessed using the Cochrane Q and Higgins I^2 tests,[31] and was deemed to be significant on the basis of conservative thresholds of Q>df for the Q tests or I^2>30%.[31] Raw data from each study were pooled. For continuous outcomes, the Hedges method was used to obtain standardized mean differences (SMD) when the studies used different psychometric scales, and weighted mean differences (WMD) were calculated when studies used the same psychometric scales. For categorical outcomes, pooled relative risks (RRs) and 95% confidence intervals (CIs) were calculated using raw data from each study. To account for clinical heterogeneity between studies and to produce a more conservative estimate of effect size,[37] data were pooled using the DerSimonian−Laird random-effects models regardless of evidence of statistical heterogeneity. For the primary outcomes (PPD and PPA), we also calculated 95% prediction intervals (PIs) to determine the potential effect size of a new study if this study were selected at random from the same population of studies currently included in our meta-analysis.[38]

We conducted prespecified stratified analyses to assess whether the effect of the DHI was altered by study quality, developed vs developing country setting, or type of DHI. These analyses were based on study quality (higher- vs lower-quality), location of study completion (developed vs developing country, as categorized by the United Nations 2022 World Economic Situation and Prospects document[39]), or route of DHI delivery (online/internet vs TAU; app vs TAU; and text message/SMS vs TAU). In addition, we conducted stratified analyses based on: (1) whether the study population was restricted to those who screened positive for PPD or PPA per study criteria (ie, either via a prespecified score on a PPD or PPA psychometric scale or self-reported depression or anxiety symptoms) or who were diagnosed with depression via formal psychological interview before randomization; and (2) the type of intervention delivered digitally (psychotherapy—defined as CBT, IPT, or mindfulness—or psychoeducation, with or without peer support; the study that provided peer support alone[40] was analyzed individually).

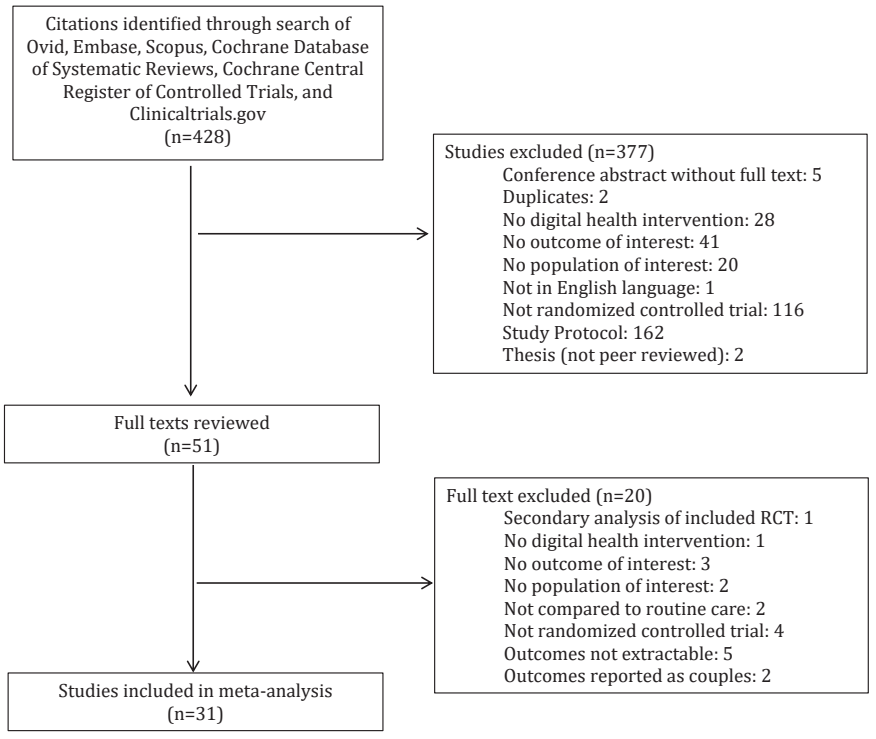
Publication bias was assessed visually using a funnel plot, whereas the Egger test statistically assessed symmetry.[41]

Pooled Results

Study selection

The literature search including ClinicalTrials.gov yielded a total of 921 citations; 453 duplicate citations were removed using the automatic duplicate finder in EndNote (Clarivate, London, United Kingdom), and additional 40 duplicates identified in both the original and updated search were removed (Figure 1). The titles and abstracts for each of the remaining 428 citations were reviewed for relevance and screened against inclusion and exclusion criteria. Most studies were excluded because they were not randomized controlled trials (116 studies) or were published study protocols (162 studies). Ultimately, 51 full texts were reviewed. Of these, 20 were excluded, most commonly because data were unabstractable because of being presented as the change between psychometric scores at baseline and at first postrandomization assessment but without the actual scores (5 studies), or because the study was described as a randomized trial but used a different study design (4 studies) or lacked outcomes of interest (3 studies). Thus, 31 studies were included in the meta-analysis.

FIGURE 1
Flow diagram for study selection



RCT, randomized controlled trial.

Lewkowitz. Digital health interventions and postpartum depression or anxiety: meta-analysis. Am J Obstet Gynecol 2024.

Study characteristics

Baseline characteristics of included studies are described in Table 1. All 31 studies were randomized trials published as full-text manuscripts. One study dichotomized analyses by parity (nulliparous and multiparous)[21]; data from this study were abstracted independently and presented in the forest plots as "Dol: nulliparous" and "Dol: multiparous," and the study was therefore counted as 2 studies in our analyses. Two studies were 3-group randomized trials (in Jiao et al's[50] study, the 3 groups were: web-based psychoeducation, home-based psychoeducation, and TAU; in Milgrom et al's study,[54] the 3 groups were: web-based CBT, in-person CBT, and TAU). Per methodological strategies described in previous meta-analyses,[34,35] data from the DHI group and the TAU group were abstracted for these 2 studies and compared. Among the 31 studies, 20 were deemed to be of higher quality,[21,22,25,27,43,45–47,50,52–62] and 11 were lower-quality.[19,20,23,24,26,40,42,44,48,49,51] Reasons for designating studies as lower-quality are described in Table 1. A total of 24 studies were conducted in developed countries[19–22,25–27,42,44–48,50–58,60,61]; only 7 were conducted in developing countries.[23,24,40,43,49,59,62] The route of delivery for the DHI varied between studies: 19 studies used an online or internet-based intervention,[20,22,24,27,40,42,44–47,50,52–57,60,61] 11 studies used a smartphone application,[19,23,25,26,43,48,49,51,58,59,62] and 1 study used a text-message/SMS-based intervention.[21] In terms of study population, 14 studies used DHIs to attempt to prevent PPD or PPA; of these, 10 studies did not include psychometric screening for or self-reported symptoms of depression and anxiety as part of their study's eligibility criteria,[19,21,23,24,40,43,46,48,50,55] whereas 4 studies screened potentially eligible participants for depression or anxiety to exclude those who screened positive.[22,25,27,51] The remaining 17 studies used DHIs to attempt to treat PPD or PPA among those who screened positive or were diagnosed with PPD or PPA. Specifically, 12 studies included only those who screened positive for depression or anxiety before randomization,[20,26,42,44,45,49,57–62] 3 studies included participants who underwent interview-based clinical assessments to diagnose major depressive disorder,[53,54,56] and 2 studies included those who self-reported symptoms of depression or anxiety before randomization.[47,52] The type of intervention delivered digitally also varied: 1 provided digital peer support,[40] 2 delivered psychoeducation with peer support,[48,56] and 9 provided psychoeducation.[21,23,43,46,47,50,51,58] Of the 20 studies that provided psychotherapy, 14 delivered CBT,[20,25–27,44,45,49,52–57,60] 6 provided mindfulness,

TABLE 1
Study characteristics

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Ashford et al,[42] 2018	England (developed)	Given birth in last 12 mo, aged >18 y, living in England, reads and writes in English, has internet access, and has scored ≥5 on the GAD-7	Receiving formal psychological treatment at start of the study, reported self-harm or suicidal ideation, or had a stillbirth or the infant was seriously ill.	iWaWa: 9 modules including CBT and mindfulness, with option for weekly email and/or text-message reminders and weekly 30-min telephone support with each module.	Psychotherapy (CBT and mindfulness)	Online	Lower (not intentional to treat)	DHI: 8 TAU: 21	DASS-21 DHI: 2.75 (3.33) TAU: 4.95 (3.91)	GAD-7 DHI: 6.63 (5.29) TAU: 8.29 (4.24)	PPD: — PPA: —	DHI: 44/46 TAU: 22/43
Bear et al,[19] 2022	New Zealand (developed)	Mother of a child aged 0—12 mo; access to a smartphone that can download applications	—	Smiling Mind's Mindfulness Foundation: smartphone application offering hundreds of hours of guided and unguided mindfulness meditations via multiple programs. Mindfulness foundation: 10 modules over 41 sessions, serving as introduction to mindfulness (not postnatal specific).	Psychotherapy (mindfulness)	Smartphone application	Lower (randomization and not intention to treat)	DHI: 27 TAU: 29	DASS-21 DHI: 3.52 (3.84) TAU: 5.59 (4.26)	DASS-21 DHI: 3.07 (3.49) TAU: 5.13 (3.70)	PPD: DHI: 4; TAU: 7 PPA: DHI: 5; TAU: 8	DHI: 34/49 TAU: 35/50
Chan et al,[43] 2019	China (developing)	First-time pregnant women with <24 wk of gestation remaining and who attended antenatal clinic at Kwong Wah Hospital, read and write Chinese or English, and were willing to consent.	Unable to give informed written consent or communicate with the interviewer.	iParent app: adapted from in-person parenting course, provides videos and articles that are on-demand with ability to ask questions to OBGYN who answers privately.	Psychoeducation	Smartphone application	Higher	DHI: 218 TAU: 225	EPDS DHI: 5.3 (4.4) TAU: 5.9 (4.7)	DASS-21 DHI: 1.9 (2.1) TAU: 1.8 (2.3)	PPD: — PPA: —	DHI: 112/330 TAU: 105/330

Lewkowitz. Digital health interventions and postpartum depression or anxiety: meta-analysis. Am J Obstet Gynecol 2024. *(continued)*

TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Danaher et al,[20] 2023	United States (developed)	NorthShore University HealthSystem patients who had EPDS score >12 during pregnancy or within 1 y of delivery, aged ≥18 y, no active suicidal ideation, access to broadband internet via desktop/laptop, tablet, or smartphone, and English language proficiency.	Active suicidal ideation (those with affirmative answers to the EPDS self-harm item were included if social work assessment deemed them low-risk for suicide).	MomMood Booster2+Perinatal Depresion Program: 6 CBT sessions comprising video and audio recordings, animations, and editable lists in browser-based web application, which opened sequentially over a 7-wk period and were available for 7 mo.	Psychotherapy (CBT)	Online	Lower (randomization)	DHI: 86 TAU: 92	PHQ-9 DHI: 5.78 (4.42) TAU: 7.48 (5.67)	DASS-21 DHI: 2.81 (2.82) TAU: 4.12 (3.83)	PPD: — PPA: —	DHI: 10/96 TAU: 3/95
Dol et al,[21] 2022 (multiparous)	Canada (developed)	Between 37+0 wk pregnant and 10 d postpartum, had daily access to mobile phone, aged ≥18 y, lived and gave birth in in Nova Scotia, and could speak and read English.	Newborn died or was expected to die before leaving the hospital; they did not have access to a mobile phone (personal or shared), were unwilling to receive text messages, declined or withdrew by not participating in primary survey, or previously participated in development or feasibility phase of this project.	53 standardized text messages providing information related to newborn care and maternal mental health in the first 6 wk postpartum; 2 messages/d for 2 wk, then daily message for weeks 3–6.	Psychoeducation	Text message	Higher	DHI: 34 TAU: 35	EPDS DHI: 8.91 (6.09) TAU: 8.0 (4.67)	Postpartum-specific anxiety scale DHI: 97.3 (22.5) TAU: 101.29 (19.01)	PPD: — PPA: —	DHI: 5/39 TAU: 6/41

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(continued)

TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Dol et al,[21] 2022 (nulliparous)	Canada (developed)	Between 37+0 wk pregnant and 10 d postpartum, had daily access to mobile phone, aged ≥18 y, lived and gave birth in in Nova Scotia, and could speak and read English.	Newborn died or was expected to die before leaving the hospital; they did not have access to a mobile phone (personal or shared), were unwilling to receive text messages, declined or withdrew by not participating in primary survey, or previously participated in development or feasibility phase of this project.	53 standardized text messages providing information related to newborn care and maternal mental health in the first 6 wk postpartum; 2 messages/d for 2 wk, then daily message for weeks 3–6.	Psychoeducation	Text message	Higher	DHI: 40 TAU: 35	EPDS DHI: 7.68 (3.97) TAU: 8.66 (5.27)	Postpartum-specific anxiety scale DHI: 106.6 (22.09) TAU: 108.2 (22.76)	PPD: — PPA: —	DHI: 4/44 TAU: 12/47

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(continued)

TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Duffecy et al,[44] 2019	United States (developed)	Aged ≥18 y, between 20 and 28 wk of gestation at time of baseline assessment, had a score between 5 and 14 on the PHQ-8 (mild-moderate depression symptoms), were able to read and speak English, and had access to internet on any device.	Diagnosis of a major depression episode, psychotic disorder, bipolar disorder, substance use disorder, or other diagnoses using the MINI; current use of psychotropic medication, intention to resume antidepressant medication after delivery (if women discontinued use during pregnancy), currently in psychotherapy, endorsed suicidality.	Sunnyside: 8-wk online prevention intervention consisting of 16 core didactic lessons and 3 postpartum booster sessions through a CBT approach with peer support (each user functioned as a virtual gardener, and each lesson that was completed grew a new plant in the garden. Peer-provided encouragement helped the plants grow).	Psychotherapy (CBT)	Online	Lower (not intention to treat)	DHI: 10 TAU: 2	PHQ-9 DHI: 2.3 (1.3) TAU: 3 (0)	—	PPD: — PPA: —	DHI: 11/18 TAU: 3/7
Fernandes et al,[22] 2022	Portugal (developed)	Aged ≥18 y, having child aged up to 18 mo, having moderate or high levels of parenting stress, female, Portuguese, a resident of Portugal; having internet access via desktop computer, tablet, or telephone.	Current self-reported diagnosis of serious mental health condition (eg, schizophrenia, substance abuse, bipolar disorder, and personality disorder).	Mindful Moment: self-guided 1-h modules (6 in total) designed for the postpartum period; 1 module intended to be opened per wk.	Psychotherapy (mindfulness)	Online	Higher	DHI: 70 TAU: 123	EPDS DHI: 10.47 (0.57) TAU: 8.66 (5.27)	HADS DHI: 9.39 (0.42) TAU: 10.03 (0.34)	PPD: — PPA: —	DHI: 76/146 TAU: 23/146

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TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Fonseca et al,[45] 2020	Portugal (developed)	Up to 3 mo postpartum, aged ≥18 y; at risk for PPD (assessed by scores above the cutoff score [5.5] on the Postpartum Depression Predictors Inventory-Revised) and/or presenting early-onset PPD symptoms (assessed by scores above the cutoff score [10] on the EPDS), having access to a computer/tablet/ smartphone and internet access at home, being able to read and speak Portuguese, being a resident of Portugal.	Presence of a serious medical condition (psychological or psychiatric) in mother or infant (self-reported).	Be A Mom: self-guided, 5 modules based on CBT that are presented with psychoeducational tools (text format, audio, video, and animations) and interactive exercises with personalized feedback tools. At end of module, a 2–3 min summary video is presented and homework activity is assigned.	Psychotherapy (CBT)	Online	Higher	DHI: 65 TAU: 82	EPDS DHI: 6.91 (0.45) TAU: 6.87 (0.41)	—	PPD: — PPA: —	DHI: 33/98 TAU: 14/96

Lewkowitz. Digital health interventions and postpartum depression or anxiety: meta-analysis. Am J Obstet Gynecol 2024. *(continued)*

TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Gün Kakaşçıand Durmaz,[23] 2022	Turkey (developing)	Mothers who gave birth via cesarean delivery at maternity service of a tertiary-level hospital in Turkey, were within 48 h of birth, who had no complication, whose infant had no complication, who had a healthy infant, who had a singleton delivery, no chronic disease, no mental disorder, aged >18 y, literate, able to communicate in Turkish, and who filled in data collection forms.	Did not meet aforementioned inclusion criteria.	Slideshow given describing education via Pecha Kucha technique, with narrative/intense visual materials.	Psychoeducation	Smartphone application	Lower (not intention to treat, primary outcome not defined)	DHI: 70 TAU: 70	—	STAI DHI: 47.41 (8.5) TAU: 53.929 (8.735)	PPD: — PPA: —	DHI: 8/78 TAU: 8/78
Haga et al,[46] 2019	Norway (developed)	Pregnant at <25 wk of gestation, aged ≥18 y, able to read and write in Norwegian, have access to the internet, and have an electronic mailing account.	—	Mamma Mia: automated internet-based program in 3 phases containing education to help participants psychologically prepare for being a mother. First: starts at 21–25 wk of gestation with 11 sessions and ends at 37 wk. Second: have 2-3 wk old infant and have 3 sessions a wk for 6 wk. Third: 10 sessions over 18 wk. In total, 44 sessions over 11.5 mo.	Psychoeducation	Text message	Higher	DHI: 392 TAU: 531	EPDS DHI: 5.2 (4.3) TAU: 5.8 (4.2)	—	PPD: DHI: 37; TAU: 63 PPA: —	DHI: 297/678 TAU: 198/684

Lewkowitz. Digital health interventions and postpartum depression or anxiety: meta-analysis. Am J Obstet Gynecol 2024. *(continued)*

TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Heller et al,[47] 2020	Netherlands (developed)	Aged ≥18 y, <30 wk pregnant, showed symptoms of anxiety, depression, or both, access to internet. They then took CES-D and HADS and were eligible if their score on the CES-D was at least 16 or score on HADS Anxiety scale was ≥8. Those with severe depression or anxiety symptoms (CES-D ≥25 or HADS-A ≥12) were allowed to participate, but they were advised to contact their general practitioner to confirm if they required other treatment.	Reported intention to harm themselves or to attempt suicide (assessed by 1 question of the Web Screening Questionnaire).	MamaKits online: 5-wk guided intervention based on problem solving treatment. Each of the 5 modules had information and examples of pregnant women with depression or anxiety doing the intervention, and homework, which was evaluated by trained coaches, who provided feedback on the assignment via secure email.	Psychoeducation	Online	Higher	DHI: 54 TAU: 65	EPDS DHI: 8.2 (5.2) TAU: 8.7 (5.9)	—	PPD: — PPA: —	DHI: 17/79 TAU: 11/80
Hsu et al,[48] 2021	Taiwan (developed)	Pregnant women at a physician prenatal clinic at Taipei's Chang Gung Obstetrics and Gynecology.	—	We'll App: mindfulness.	Psychotherapy (mindfulness)	Smartphone application	Lower (randomization, not intention to treat)	DHI: 30 TAU: 30	EPDS DHI: 1.69 (0.298) TAU: 1.8 (0.475)	—	PPD: — PPA: —	DHI: 0/30 TAU: 0/30

Lewkowitz. Digital health interventions and postpartum depression or anxiety: meta-analysis. Am J Obstet Gynecol 2024. *(continued)*

TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Huang et al,[40] 2021	China (developing)	Aged ≥18 y, first-time mothers with healthy infants, ability to answer the questionnaires, and internet access by mobile phone or computer.	"If they or their infants had serious diseases."	Online learning forum, communication area, ask the expert forum, infant at home forum, all developed according to self-efficacy theory and social exchange theory.	Peer support	Online	Lower (not intention to treat)	DHI: 18 TAU: 18	EPDS DHI: 5.78 (2.23) TAU: 8.28 (2.66)	—	PPD: — PPA: —	DHI: 2/20 TAU: 2/20
Jannati et al,[49] 2020	Iran (developing)	Women aged ≥18 y, at least weekly access to the internet and mobile phone, giving birth in last 6 mo, sufficient Persian language skills to complete survey, EPDS ≥13, and interview with psychologist to confirm PPD diagnosis.	—	Happy Mom: 8 lessons over 8 wk as a storybook showing how similar mothers with PPD dealt with or improved their mental health. Each lesson lasted 45–60 min and ended with assignments.	Psychotherapy (CBT)	Smartphone application	Lower (not intention to treat)	DHI: 38 TAU: 37	EPDS DHI: 8.18 (1.5) TAU: 15.01 (2.9)	—	PPD: — PPA: —	DHI: 1/39 TAU: 2/39
Jiao et al,[50] 2019	Singapore (developed)	First-time mothers who delivered at a tertiary care center in Singapore.	—	Web-based postnatal psychoeducational intervention accessible for 1 mo.	Psychoeducation	Online	Higher	DHI: 64 TAU: 64	EPDS DHI: 4.73 (9.94) TAU: 5.14 (10.55)	—	PPD: — PPA: —	DHI: 7/68 TAU: 5/68

Lewkowitz. Digital health interventions and postpartum depression or anxiety: meta-analysis. Am J Obstet Gynecol 2024. *(continued)*

TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Koçak et al,[51] 2021	Turkey (developed)	Aged ≥18 y and having given vaginal or cesarean delivery, having Android phone and internet connection, having an infant with normal birthweight and an APGAR score of ≥8, having developed no postpartum complications; speak and understand Turkish.	Being illiterate, having complications in the mother or the newborn (including infant in the intensive care unit), presence of anomaly in the newborn, presence of chronic disease or disability in mother (self-report or clinically diagnosed), disability in the mother (physical, mental, vision, hearing, etc.), having given birth to twins, having been diagnosed with anxiety and depression (self-report), having had a high-risk pregnancy (pregnancy hypertension, gestational diabetes, etc.), having divorced during pregnancy or being in process of divorce.	BebekveBiz: on-demand support and education on maternal care, infant care, breastfeeding, and the ability to interact with a consultant at any time. The program also sent notifications every 5–10 h to increase motivation of the mothers.	Psychoeducation	Smartphone application	Lower (not intention to treat)	DHI: 50 TAU: 48	EPDS DHI: 6.68 (6.51) TAU: 8.81 (8.32)	STAI DHI: 42.33 (0.72) TAU: 42.55 (0.79)	PPD: — PPA: —	DHI: 12/62 TAU: 14/62

Lewkowitz. Digital health interventions and postpartum depression or anxiety: meta-analysis. Am J Obstet Gynecol 2024.

(continued)

TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Liu et al,[24] 2022	China (developing)	Voluntary participation; aged 20–40 y; 36-38 wk pregnant; diagnosis of pregnancy; "no examination or treatment affecting endocrine function within half a year"; able to use a smartphone for >3 y; can use various mobile phone applications.	Severe physical disease and mental disorder; experience in mindfulness training; taking antianxiety medication or antidepressants; high-risk pregnancy status diagnosed by obstetrician.	We'll App: smartphone application that aims to provide mindfulness and perceived social support interventions for puerperia. Received the app intervention 3 times a wk for 8 wk.	Psychotherapy (mindfulness)	Online	Lower (randomization, not intention to treat)	DHI: 65 TAU: 65	—	—	PPD: DHI: 41; TAU: 52 PPA: —	DHI: 0/65 TAU: 0/65
Loughnan et al,[52] 2019	Australia (developed)	Within 12 mo postpartum; aged >18 y; fluent in written and spoken English; Australian resident; computer and internet access; self-report symptoms of anxiety and/or depression above clinical threshold (ie, GAD-7 and/or PHQ-9 total score ≥10), willing to provide contact details for their general practitioner.	Current substance use or dependence; use of benzodiazepines; diagnosis of schizophrenia or bipolar disorder; started psychotherapy <4 wk ago or medication <8 wk ago for anxiety/depression. Applicants with severe depression (PHQ-9 total score ≥23) or current suicidality.	MUMentum postnatal: 3 online CBT lessons that had to be completed within active treatment period of 6 wk.	Psychotherapy (CBT)	Online	Higher	DHI: 50 TAU: 47	EPDS DHI: 8.82 (4.96) TAU: 13.34 (4.96)	GAD-7 DHI: 6.66 (4.23) TAU: 9.97 (4.22)	PPD: — PPA: —	DHI: 32/69 TAU: 20/62

Lewkowitz. Digital health interventions and postpartum depression or anxiety: meta-analysis. Am J Obstet Gynecol 2024. *(continued)*

TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Milgrom et al,[53] 2016	Australia (developed)	Australian residency; aged ≥18 y; English speaking; <1 y postpartum; internet access with regular email use; EPDS score of 11−23 and score of <3 on item #10 (thoughts of self-harm). After this initial assessment, underwent structured clinical interview to confirm diagnosis of major or minor depressive disorder.	Current substance abuse; current and past manic/ hypomanic symptoms; PTSD; alcohol abuse or dependence; depression with psychotic features; risk of suicide per risk protocol; current active treatment for depression (medication or psychotherapy).	MumMoodBooster: 6 interactive CBT sessions designed to be completed 1 per wk, each with text animations, videos introductions, and case vignettes; personalization encouraged; self-monitoring via homework; also conducted with peer-monitored forum and telephone-based coach for 30 min per wk sessions.	Psychotherapy (CBT)	Online	Higher	DHI: 19 TAU: 22	BDI DHI: 14.5 (7.2) TAU: 23.0 (7.5)	DASS-21 DHI: 4.2 (5.5) TAU: 5.4 (3.0)	PPD: — PPA: —	DHI: 2/21 TAU: 0/22

Lewkowitz. Digital health interventions and postpartum depression or anxiety: meta-analysis. Am J Obstet Gynecol 2024. *(continued)*

TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Milgrom et al,[54] 2021	Australia (developed)	EPDS scores of 11–25; aged ≥18 y; 6 wk to 1 y postpartum; familiarity with internet and email; agreeing to be assigned to any of the 3 experimental conditions. After this initial assessment, underwent structured clinical interview to confirm diagnosis of major or minor depressive disorder.	At risk of suicide according to follow-up questions to EPDS score >0 on question 10 during screening. In second phase, excluded if current substance abuse; manic or hypomanic symptoms or depression with psychotic features; PTSD; risk of suicide; under treatment for depression (medication or therapy).	MumMoodBooster: 6 interactive CBT sessions designed to be completed 1 per wk, each with text animations, videos introductions, and case vignettes; personalization encouraged; self-monitoring via homework; also conducted with peer-monitored forum and telephone-based coach for 30 min per wk sessions.	Psychotherapy (CBT)	Online	Higher	DHI: 32 TAU: 33	BDI DHI: 11.63 (8.98) TAU: 18.85 (10.16)	DASS-21 DHI: 1.81 (2.61) TAU: 4.73 (5.22)	PPD: — PPA: —	DHI: 10/39 TAU: 6/38
Monteiro et al,[55] 2020	Portugal (developed)	Early postpartum period (up to 3 mo postpartum); age ≥18 y; low risk for PPD (Postpartum Depression Predictors Inventory-Revised <5.5); have internet access at home; resident of Portugal; understand Portuguese.	Serious medical condition (physical or psychiatric); infant had serious health condition (both self-reported).	Be A Mom: 5 sequential online CBT modules, averaging 45 min in length, once a wk.	Psychotherapy (CBT)	Online	Higher	DHI: 104 TAU: 145	EPDS DHI: 5.26 (0.33) TAU: 6.19 (0.29)	—	PPD: — PPA: —	DHI: 87/191 TAU: 31/176

Lewkowitz. Digital health interventions and postpartum depression or anxiety: meta-analysis. Am J Obstet Gynecol 2024. *(continued)*

TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Nishi et al,[25] 2022	Japan (developed)	Pregnant women with Luna Luna Baby user ID; aged ≥20 y; 16–20 wk of gestation; no diagnosis of major depressive episode in past month per self-administered interview; no bipolar episode lifelong.	—	Luna Luna smartphone application: 6 CBT modules, each lasting approximately 5 min.	Psychotherapy (CBT)	Smartphone application	Higher	DHI: 1086 TAU: 1260	EPDS DHI: 6.47 (0.12) TAU: 6.5 (0.12)	—	PPD: — PPA: —	DHI: 804/2509 TAU: 704/2508
O'Mahen et al,[56] 2014	United Kingdom (developed)	Aged >18 y; given birth to live infant within the last year; scored >12 on EPDS; did not experience substance abuse or psychosis; spoke English. Then diagnosed with major depressive disorder via diagnostic clinical assessment.	—	Netmums: 12-session postpartum modules, each with interactive exercises where conversations can be held with similar mothers in room moderated by peers; focus on behavioral activation (a component of CBT); weekly phone call.	Psychotherapy (CBT)	Online	Higher	DHI: 37 TAU: 34	EPDS DHI: 11.04 (4.71) TAU: 14.26 (5.11)	GAD-7 DHI: 8.71 (4.61) TAU: 11.28 (5.49)	PPD: — PPA: —	DHI: 10/41 TAU: 13/41

Lewkowitz. Digital health interventions and postpartum depression or anxiety: meta-analysis. Am J Obstet Gynecol 2024. *(continued)*

TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Pugh et al,[57] 2016	Canada (developed)	Aged ≥18 y; gave birth to an infant within last 12 mo; residing in Saskatchewan; self-reported access to and comfort using a computer and the internet; score of ≥10 on EPDS; consent to notify physician of participation; not receiving other psychotherapy; if taking medication, stable dose for >1 mo.	No past or present psychotic mental illness (schizophrenia), bipolar disorder; no current suicide plan or intent.	Maternal Depression Online: 7 online modules (1 a wk), each with a range of media (text, graphics, animation, audio, and video); also, a therapist would email participant weekly to provide support and encouragement and answer questions.	Psychotherapy (CBT)	Online	Higher	DHI: 19 TAU: 21	EPDS DHI: 8.68 (3.8) TAU: 12.71 (3.7)	DASS-21 DHI: 42.33 (0.73) TAU: 7.62 (6.74)	PPD: — PPA: —	DHI: 6/25 TAU: 4/25
Sawyer et al,[58] 2019	Australia (developed)	EPDS score ≥7; at least 1 self-reported parenting problem; literacy in English; access to a smartphone.	—	eMums Plus: nursing led, 4-mo parenting educational intervention delivered via smartphone application when infants were 2–6 mo old. Components included chat, timeline, resources, and contacts/ assistance.	Psychoeducation	Smartphone application	Higher	DHI: 60 TAU: 58	EPDS DHI: 7.9 (—) TAU: 8.7 (—)	—	PPD: — PPA: —	DHI: 15/72 TAU: 3/61
Seo et al,[26] 2022	Republic of Korea (developed)	Score of ≥9 on EPDS; within 1 y of childbirth; used Android-based smartphones.	Receiving psychiatric treatment.	Happy Mother App: provides psychoeducation and CBT, previously shown to be of "superior quality" in previous research; used for 8 wk.	Psychotherapy (CBT)	Smartphone application	Lower (not intention to treat)	DHI: 37 TAU: 36	EPDS DHI: 10.7 (4.64) TAU: 13.03 (6.19)	—	PPD: — PPA: —	DHI: 13/50 TAU: 14/50

Lewkowitz. Digital health interventions and postpartum depression or anxiety: meta-analysis. Am J Obstet Gynecol 2024. *(continued)*

TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Sjömark et al,[27] 2022	Sweden (developed)	Score ≤5 on Likert scale of overall childbirth experience and/or exposure to immediate CD and/or severe hemorrhage (>2 L) following childbirth.	Aged <18 y; no ability to use internet; unable to speak, read, or write Swedish; severe mental illness according to participant's statement; stillbirth and neonatal death; ongoing psychological treatment.	Two parts: Part 1: 6 audio-visual modules (or could download text), 1 per wk, with homework assignments and ability to talk to psychologist on demand; 6 steps including homework. If completed this part and diagnosed with PTSD, then eligible for second part. Part 2: 8 modules of individualized, structured content that included weekly therapeutic support via email.	Psychotherapy (CBT)	Online	Higher	DHI: 69 TAU: 85	EPDS DHI: 8.76 (4.19) TAU: 8.62 (4.47)	—	PPD: — PPA: —	DHI: 77/132 TAU: 54/134

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TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Sun et al,[59] 2021	China (developing)	Aged ≥18 y; in 12th to 20th wk of gestation; singleton pregnancy; no plan to terminate pregnancy; plan to receive antenatal care and deliver at study hospital; completed junior high school or above; positive depressive symptoms with EPDS >9 or a PHQ-9 >4; able to use the app on smartphone for the study; able to understand and respond to questionnaire.	At risk of suicide or self-harm; currently receiving psychiatric treatment or using psychiatric medications; history of substance abuse or addiction in the past 6 mo; previous experience with mindfulness meditation; declined to participate.	Spirits Healing: 8-wk mindfulness training program containing 8 sessions composed of thematic curriculum via text, audio, and visual materials, followed by writing in mindfulness journal.	Psychotherapy (mindfulness)	Smartphone application	Higher	DHI: 52 TAU: 40	EPDS DHI: 6.77 (4.693) TAU: 6.25 (5.098)	GAD-7 DHI: 4.31 (2.995) TAU: 4.1 (3.967)	PPD: — PPA: —	DHI: 24/84 TAU: 34/84

Lewkowitz. Digital health interventions and postpartum depression or anxiety: meta-analysis. Am J Obstet Gynecol 2024. *(continued)*

TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Van Lieshoutet al,[60] 2021	Canada (developed)	Aged ≥18 y; infant aged <12 mo; lived in Ontario; EPDS score of ≥10; live in Ontario.	—	One-day interactive, virtual workshop with didactic teaching, group exercises and discussions, and roleplay over 4 modules.	Psychotherapy (CBT)	Online	Higher	DHI: 165 TAU: 192	EPDS DHI: 11.65 (4.83) TAU: 14.04 (4.54)	GAD-7 DHI: 7.97 (5.54) TAU: 10.76 (5.1)	PPD: — PPA: —	DHI: 37/202 TAU: 9/201
Vigod et al,[61] 2021	Canada (developed)	Identified as mother (inclusive of all genders, adoptive and birth parents), aged ≥18 y with infant aged 0–12 mo living with them; resided in Ontario; had EPDS score of ≥10.	Individuals with active suicidal ideation, mania, psychosis, or a substance or alcohol use disorder; those without internet access; those unable to read or write in English.	Mother Matters: 10 weekly topics following interpersonal therapy targets; each week; therapists would post educational information about the weekly topic to forum with a set of questions for group to answer and monitor responses.	Psychotherapy (interpersonal therapy)	Online	Higher	DHI: 37 TAU: 40	EPDS DHI: 11.3 (4.54) TAU: 12 (4.79)	—	PPD: DHI: 23; TAU: 20 PPA: —	DHI: 13/50 TAU: 8/48

Lewkowitz. Digital health interventions and postpartum depression or anxiety: meta-analysis. Am J Obstet Gynecol 2024. *(continued)*

TABLE 1
Study characteristics *(continued)*

Author (y)	Country (UN category)	Inclusion criteria	Exclusion criteria	Intervention	Intervention type (type of psychotherapy, if psychotherapy)	Intervention delivery	Quality	First postpartum follow-up (sample size)	PPD (psychometric scale), mean (SD)	PPA (psychometric scale), mean (SD)	Screen positive (PPD vs PPA)	Loss to follow-up (number completed final study assessment/ number initially randomized)
Yang et al,[62] 2019	China (developing)	Aged >18 y; 24 −30 wk of gestation; low-risk pregnancy at start of intervention; internet access; fluent in Chinese and able to complete the questionnaires; elevated depressive or anxious symptoms (PHQ-9 >4, GAD-7 >4).	History or current diagnosis of psychosomatic disease (physical symptoms or illness that results from interplay of psychosocial and physiological process, such as hypertension, diabetes mellitus, or asthma); current substance abuse; participation in psychological therapy or stress reduction program; history of suicide attempt; current use of psychoactive drug; high level of depression PHQ-9 >14, or GAD-7 >14; regular mind-body practice (including yoga, meditation).	4 mindfulness modules given over 8 wk through WeChat platform; included homework practice and ability to interact with each other and researchers.	Psychotherapy (mindfulness)	Smartphone application	Higher	DHI: 52 TAU: 50	PHQ-9 DHI: 3.58 (2.32) TAU: 6.26 (3.31)	GAD-7 DHI: 2.97 (2.34) TAU: 5.26 (2.88)	PPD: — PPA: —	DHI: 10/62 TAU: 11/61

—, data not included in manuscript; *BDI*, Beck Depression Inventory; *CBT*, cognitive behavioral therapy; *CD*, Cesarean delivery; *CES-D*, Center for Epidemiological Studies Depression Scale; *DASS-21*, Depression Anxiety Stress Scale-21 items (either depression or anxiety subscales); *DHI*, digital health intervention; *EPDS*, Edinburgh Postnatal Depression Scale; *GAD-7*, Generalized Anxiety Disorder-7; *HADS*, Hospital Anxiety and Depression Scale (anxiety subscale); *OBGYN*, obstetrician-gynecologist; *PHQ*, Patient Health Questionnaire; *PPA*, postpartum anxiety; *PPD*, postpartum depression; *PTSD*, posttraumatic stress disorder; *STAI*, State-Trait Anxiety Inventory; *TAU*, treatment as usual; *UN*, United Nations.

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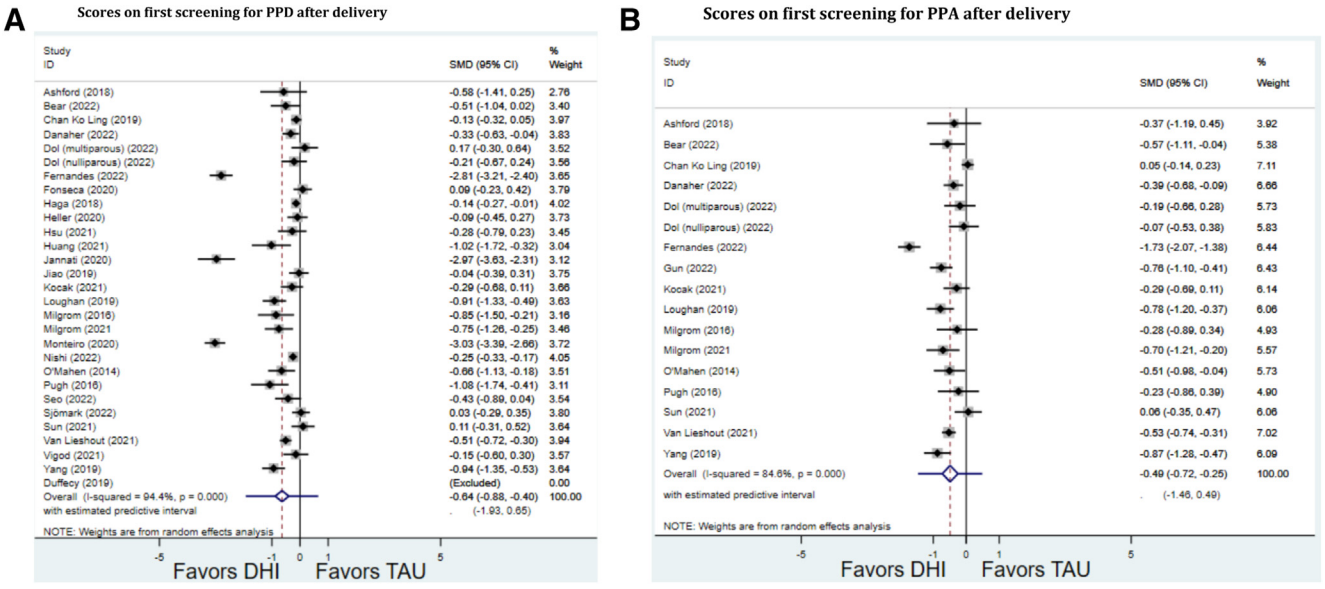
FIGURE 2
Scores on First Postnatal Screen for PPD/PPA After DHI vs TAU



A, Scores on first screening for PPD after delivery. **B,** Scores on first screening for PPA after delivery.

CI, confidence interval; *DHI*, digital health intervention; *PPA*, postpartum anxiety; *PPD*, postpartum depression; *SMD*, standardized mean difference; *TAU*, treatment as usual.

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[19,22,24,48,59,62] 1 delivered IPT,[61] and 1 included a program combining mindfulness and CBT.[42]

Synthesis of results and risk of bias of included studies

In total, 5532 participants received a DHI and 5492 participants received TAU across the 31 individual studies (which were analyzed as 32 studies because of the dichotomous study population of Dol et al[21]), with sample sizes ranging from 18 to 2509 participants and follow-up lasting from 2 days until 1 year after randomization. Inclusion and exclusion criteria differed significantly across studies; for example, most studies recruited participants exclusively in person during prenatal care clinic visits or birth hospitalization, whereas 7 studies recruited participants partly or exclusively through social media or printed advertisements in community space. The time frame of the first screen for PPD or PPA was heterogeneous: although 28 studies first assessed for PPD or PPA from 4 to 12 weeks postpartum, the range extended from <1 week after delivery to 32 weeks postpartum.

Psychometric scales used to screen for PPD or PPA varied across studies (Table 1). Of the 29 studies that screened for PPD, 22 studies used the EPDS, 3 used the Patient Health Questionnaire-9,[63] 2 used the depression subscale of the Depression Anxiety Stress Scale-21 (DASS-21),[64] and 2 used the Beck Depression Inventory.[65] Four studies presented data on screen-positive rates for PPD (although the definition of screening positive differed across studies: 1 study defined screen-positive PPD as a mild score or higher on the DASS-21,[19] and the 3 other studies as EPDS score of ≥ 9[24] or ≥ 10[46,61]). For PPA, 6 of the 17 studies that screened for PPA used the GAD-7, 6 used the anxiety subscale of the DASS-21,[64] 2 used the State-Trait Anxiety Inventory,[66] Dol et al[21] used the Postpartum Specific Anxiety Scale for the nulliparous and multiparous cohorts,[67] and 1 study used the Hospital Anxiety and Depression Scale.[68] Only 1 study provided data on screen-positive rates for PPA, defined as at least a mild score on the DASS-21 anxiety subscale.[19]

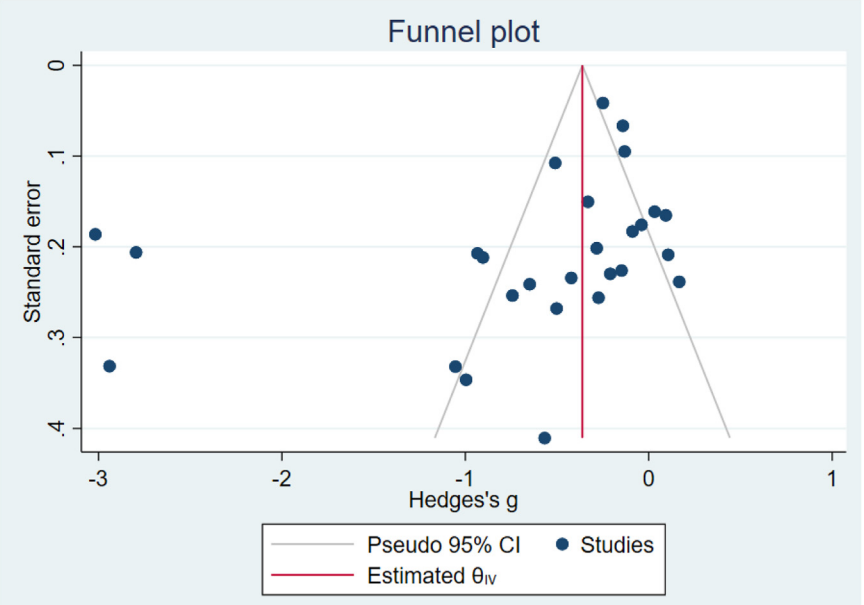
Compared with TAU, DHIs significantly, although modestly, reduced both PPD symptoms (29 studies: SMD, −0.64 [95% CI, −0.88 to −0.40]; 95% PI, −1.93 to 0.65) and PPA symptoms (17 studies: SMD, −0.49 [95% CI, −0.72 to −0.25]; 95% PI, −1.96 to 0.49) (Figure 2). A high amount of interstudy heterogeneity was identified for both PPD and PPA (I^2 was 94.4% and 83.4%, respectively). For both primary outcomes, the funnel plots did not show asymmetry, and the Egger test confirmed an absence of publication bias for PPD (P=.12) and PPA (P=.85) (Figure 3).

Secondary outcomes shown in Figure 4 include scores on the EPDS for PPD and on the GAD-7 for PPA, and screen-positive rates and overall LTFU rates. When analyses were limited to studies that conducted PPD or PPA screening with these scales, DHIs significantly reduced both EPDS scores (22 studies: WMD, −0.64 [95% CI, −0.92 to −0.35]) and GAD-7 scores (6 studies: WMD, −0.52 [95% CI, −0.78 to −0.25]), although interstudy

heterogeneity persisted (I^2 95.6% for PPD and I^2 59.5% for PPA). There were no differences in rates of screening positive for PPD (n=4) or PPA (n=1) among those randomized to DHI vs TAU. In terms of LTFU, 57.1% (n=3158) of those randomized to the DHI completed the final study assessment, as opposed to 66.2% (n=3635) of those randomized to TAU; thus, those randomized to the DHI had 38% higher risk of not completing the study comparatively (pooled RR, 1.38 [95% CI, 1.18−1.62]).

Forest plots for stratified analyses or primary outcomes and for all secondary outcomes are included in Appendix 3. In general, the effect of DHIs on primary and secondary psychological outcomes was similar among the primary analyses and analyses stratified by study quality, country setting, type of DHI (web/online, app, or text message), and whether the participants screened positive (or were diagnosed with or self-reported symptoms) for depression or anxiety (Table 2). Nearly all stratified analyses showed high amount of interstudy heterogeneity (Table 2). For the primary PPD outcome, interventions that provided psychotherapy had a larger effect on PPD and PPA compared with those that delivered psychoeducation with or without peer support (psychotherapy: PPD [19 studies]: SMD, −0.87 [95% CI, −1.26 to −0.48] and PPA [11 studies]: SMD, −0.60 [95% CI, −0.91 to −0.30]; vs psychoeducation: PPD [9 studies]: SMD, −0.15 [95% CI, −0.22 to −0.06] and PPA [6 studies]: SMD, −0.29 [95% CI, −0.57 to 0.00]). The risk of not completing the final study assessment was higher among those randomized to DHIs that were web/online-based (19 studies: RR, 1.77 [95% CI, 1.46−2.15]) or that delivered psychotherapy (20 studies: RR, 1.52 [95% CI, 1.22−1.90) compared with those randomized to DHIs overall (RR, 1.38 [95% CI, 1.18−1.62]). Of note, there was no difference in LTFU rates between those randomized to apps vs to TAU (RR, 1.04 [95% CI, 0.91−1.19]).

FIGURE 3
Funnel plot with pseudo 95% CIs for all studies included for postpartum depression screening



CI, confidence interval.

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Discussion

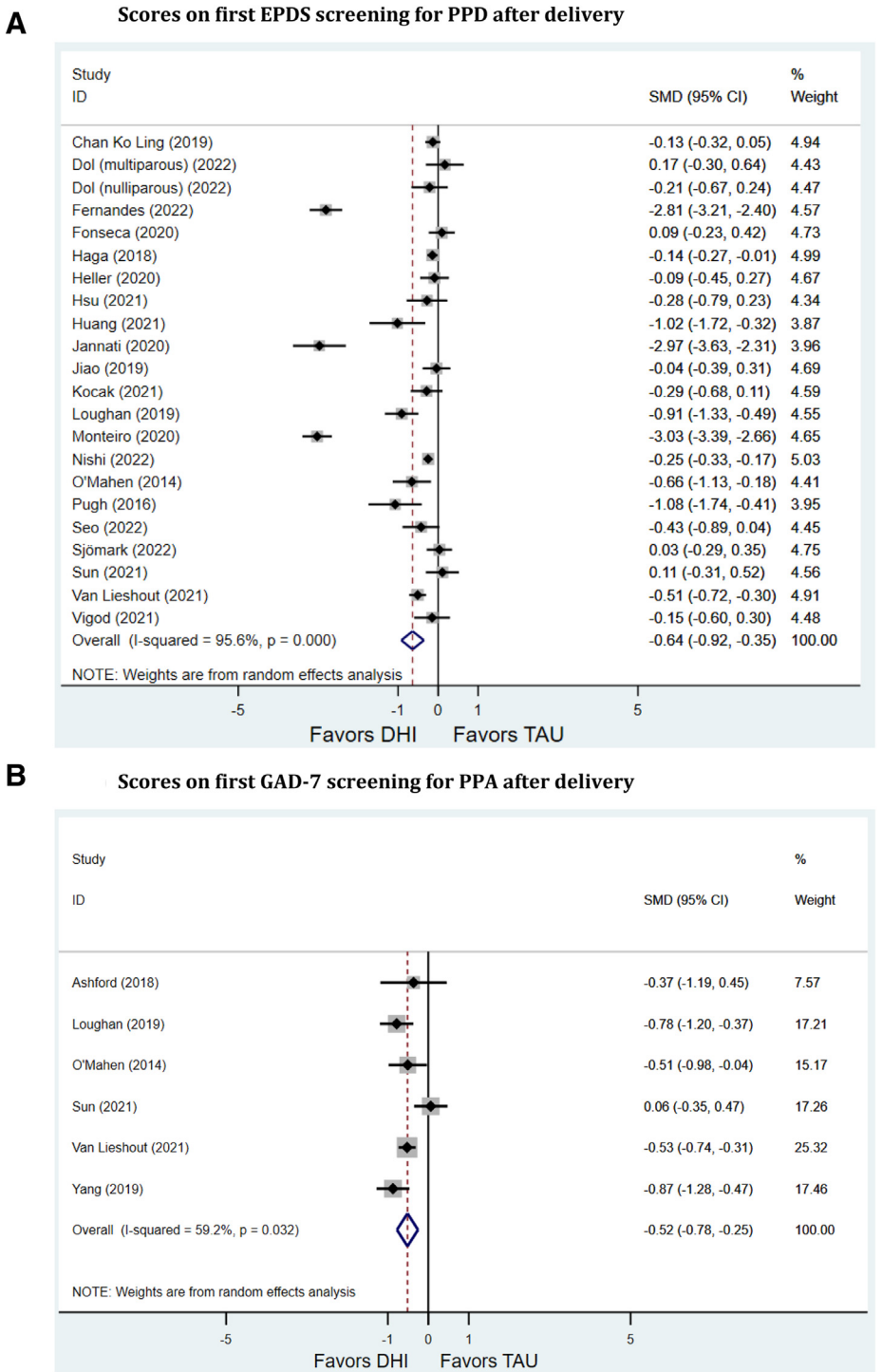
Principal results

In this meta-analysis of randomized trials analyzing the effect of DHIs on PPD and PPA, a modest but statistically significant reduction in scores on psychometric scales assessing PPD and PPA was identified among those randomized to DHIs overall and when PPD and PPA were assessed with EPDS and GAD-7, respectively. This effect was more pronounced when the DHI delivered psychotherapy (CBT, IPT, or mindfulness) compared with psychoeducation with or without peer support. DHIs had similarly modest effects on preventing PPD or PPA among those who screened negative (or were not screened) for these conditions upon randomization and on treating PPD and PPA among those who screened positive or were diagnosed with depression or anxiety at randomization. Although LTFU rates were higher among those randomized to DHIs than those randomized to TAU, this difference was driven by a high rate of dropout identified in studies using web/online interventions: there was no difference in LTFU rates between those randomized to apps and TAU. These findings suggest that although all DHIs seem to improve postpartum mental health, those that provide psychotherapy and are delivered via smartphone applications may be the most effective at improving psychological outcomes and retaining participant engagement, respectively.

Comparisons with previous work

Our findings are consistent with those reported in previous meta-analyses,[15−18] which also noted a small but statistically significant improvement in psychometric scales measuring PPD or PPA but no difference in screen-positive rates for PPD between those randomized to DHIs and TAU. However, unlike the previous meta-analyses,[15−18] which reported mostly pooled psychometric outcomes, we conducted stratified analyses based on factors that could plausibly impact the effectiveness of DHI, such as study quality, country of origin, type of intervention delivered (psychoeducation or psychotherapy), and type of DHI used (online, app, or SMS). In addition, unlike previous meta-analyses—which presented study populations as homogeneous[15−18]—one of our analyses stratified the primary studies into

FIGURE 4
Secondary outcomes after DHI vs TAU for PPD or PPA



A, Scores on first EPDS screening for PPD after delivery. **B,** Scores on first GAD-7 screening for PPA after delivery. **C,** Screen positive for PPD. **D,** Screen positive for PPA. **E,** Loss to follow-up rates.

CI, confidence interval; *DHI*, digital health intervention; *EPDS*, Edinburgh Postnatal Depression Scale; *GAD-7*, Generalized Anxiety Disorder-7; *LTFU*, loss to follow-up; *PPA*, postpartum anxiety; *PPD*, postpartum depression; *RR*, relative risk; *SMD*, standardized mean difference; *TAU*, treatment as usual.

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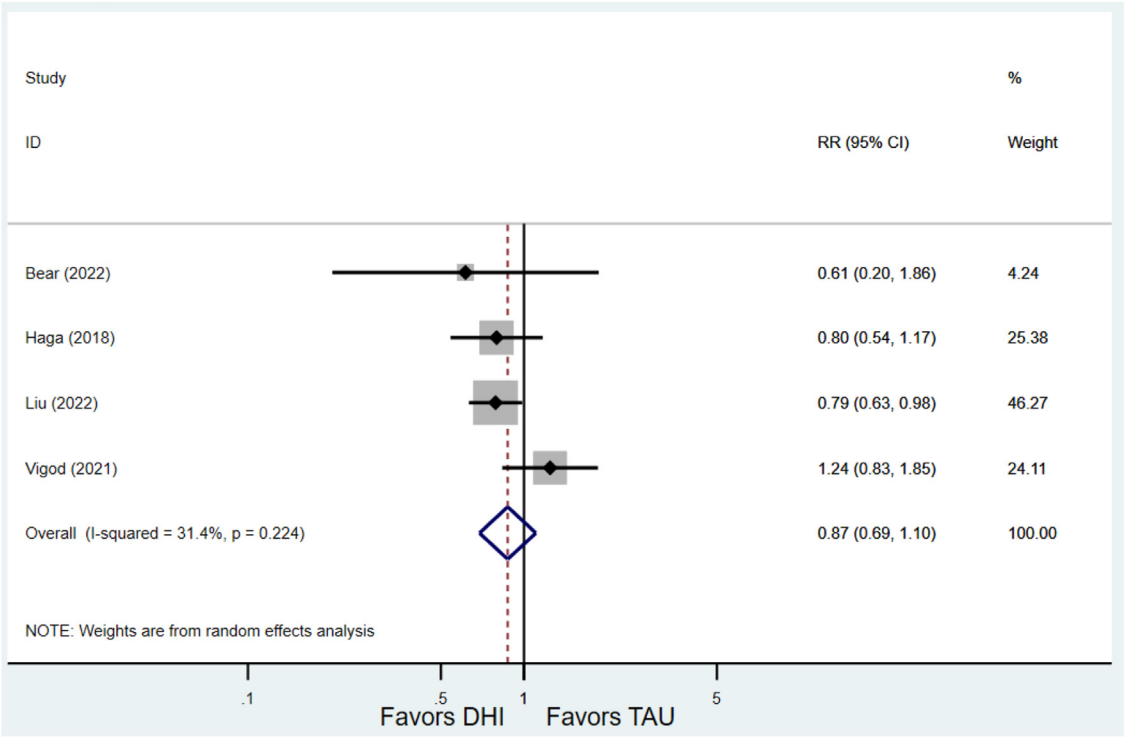
FIGURE 4
Continued

C **Screen positive for PPD**



D **Screen positive for PPA**

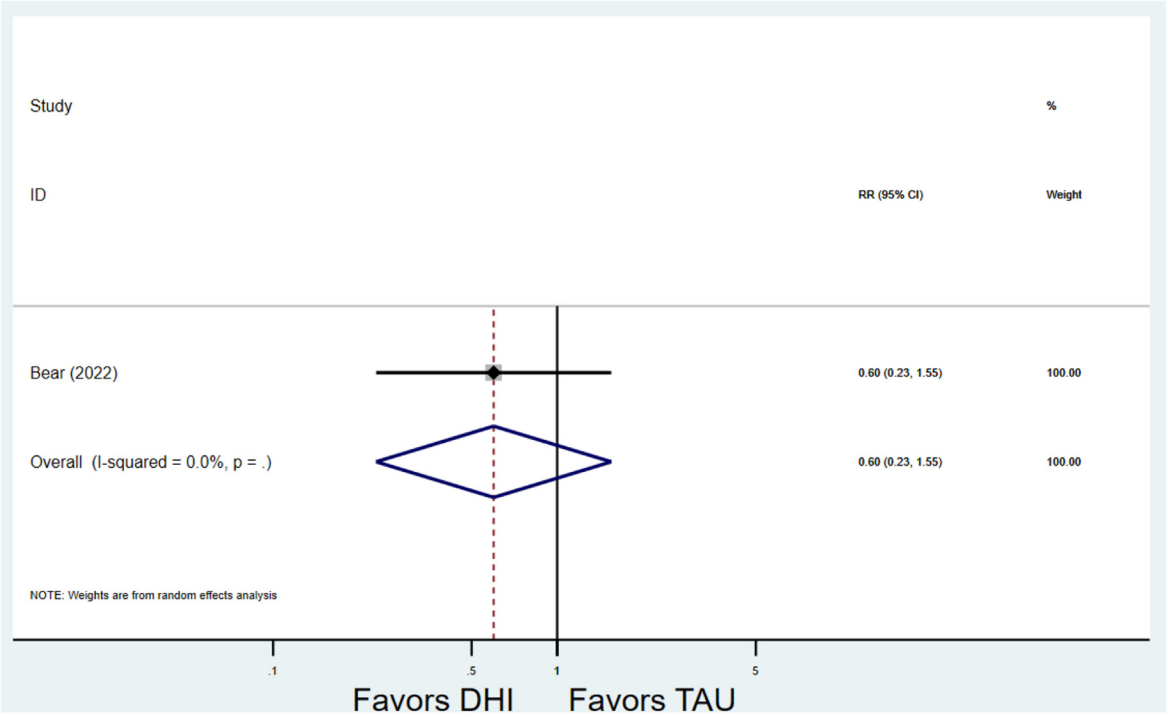


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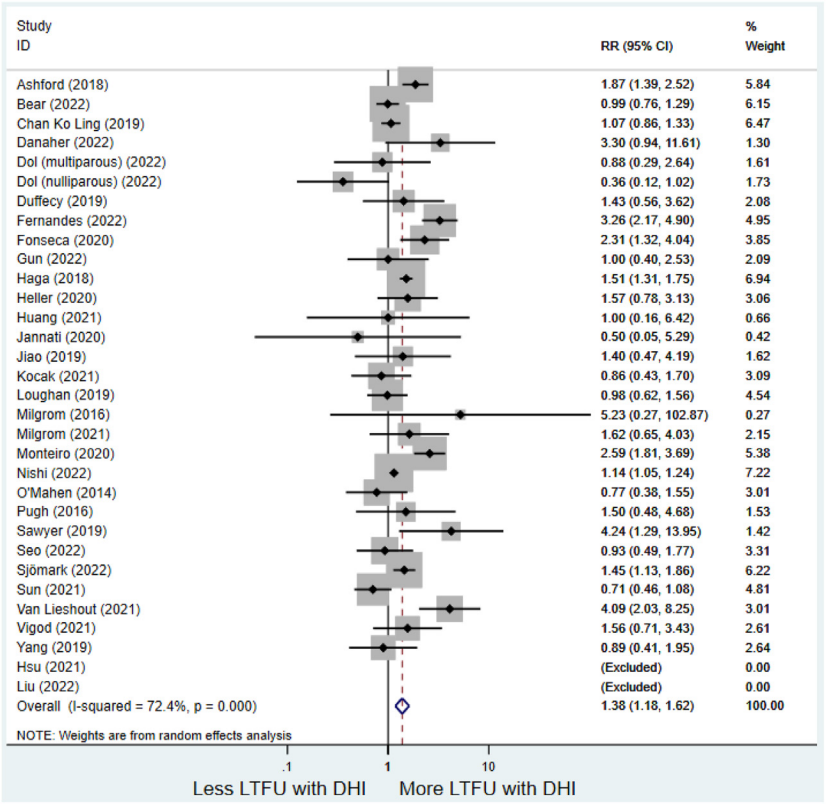
FIGURE 4
Continued

E **Loss to follow-up rates**



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those in which potential participants were required to screen positive for or self-reported depressive or anxiety symptoms to be randomized. Interestingly, this stratified analysis concluded that DHI had a similar effect on postpartum psychometric scales regardless of whether the participant screened positive for depression or anxiety. Altogether, our findings not only support those from previous meta-analyses[15–18] but add depth to the relationship between DHI and PPD and PPA.

Clinical implications

PPD and PPA are among the most common conditions in the postpartum period.[1,2] Despite the fact that psychoeducation[3] and psychotherapy[4–6] have been shown to effectively prevent and treat PPD and PPA, few people who have PPD or PPA are able to access these interventions,[7] potentially because of a lack of skilled mental health professionals.[8] DHIs are accessible to nearly all who reside in the United States,[10–12] bypass barriers associated with reduced adherence to in-person postpartum care,[13,14] and are inherently scalable without relying on skilled mental health professionals for dissemination. The fact that DHIs are more effective than TAU in terms of reducing scores on psychometric scales assessing for PPD and PPA is promising for PPD/PPA prevention and treatment. More specifically, widespread incorporation of DHIs that provide evidence-based psychoeducation or psychotherapy could provide modest population-wide reductions in PPD and PPA symptoms, as measured by psychometric scales. Furthermore, the benefits to DHI noted in the subgroup of studies conducted in developing countries offers a scalable potential solution to the global burden of untreated perinatal mental health conditions.

Strengths and limitations

Our study has several strengths. First, we used a predesigned protocol in which an expert research librarian conducted a comprehensive search strategy, and 2 researchers independently screened all abstracts and potentially eligible full manuscripts for inclusion before independently abstracting data, which reduced bias. We also updated our search during the review process because of the publication of multiple potentially eligible randomized trials after the initial search was complete, which allowed us to base our conclusions on the most up-to-date data available. In addition, we conducted multiple stratified analyses, which allowed us to assess the impact of study quality, study setting, type of intervention delivered, and type of DHI on the effectiveness of DHIs for PPD and PPA treatment. Lastly, we pooled data from studies using random-effects models, which is a more conservative strategy that helps reduce the potential effect of heterogeneity between studies.

Nevertheless, limitations should be considered. First, the findings of our meta-analysis carry forward the limitations of primary studies, including lower-quality studies. However, the persistence of our findings within the subgroup of studies considered high-quality provides reassurance against biased findings. Second, there was excessive clinical and statistical heterogeneity in our analysis, with multiple different psychometric scales used, varying eligibility criteria for entry into each included study, and various study interventions, even within similar categories of DHIs. We attempted to reduce the effect of this heterogeneity by conducting multiple secondary analyses and subgroup analyses limited to studies that contained the same psychometric scale, required participants to screen positive for PPD, or used the same individual type of DHI. Although these additional analyses may have reduced the effect of heterogeneity on our outcomes, it would be impossible to eliminate the

TABLE 2
Pooled and stratified analyses of the effect of digital health interventions vs treatment as usual on postpartum depression or postpartum anxiety

Outcome	Number of studies[a]	Digital health intervention (n)	Treatment as usual (n)	Measure of effect	Effect size (95% confidence interval)	I^2	*P* value from DHI vs TAU
Score on postpartum depression scale[a]	29	2963	3442	SMD[b]	−0.64 (−0.88 to −0.40)	94.4%	<.001
Higher quality[a]	20	2659	3129	SMD[b]	−0.60 (−0.88 to −0.31)	95.5%	<.001
Lower quality	9	304	313	SMD[b]	−0.77 (−1.28 to −0.26)	88.0%	.003
Developed country[a]	24	2585	3072	SMD[b]	−0.58 (−0.85 to −0.32)	94.6%	<.001
Developing country	5	378	370	SMD[b]	−0.95 (−1.77 to −0.13)	95.1%	.023
Online/web-based intervention	18	1299	1613	SMD[b]	−0.75 (−1.15 to −0.34)	95.8%	<.001
Smartphone application	9	1590	1755	SMD[b]	−0.56 (−0.88 to −0.24)	90.1%	.001
Text-message[a]	2	74	70	SMD[b]	−0.03 (−0.40 to 0.34)	22.4%	.88
Screen-positive for depression or anxiety	16	761	814	SMD[b]	−0.63 (−0.91 to −0.34)	85.5%	<.001
Screen-negative or no screening[a]	13	2202	2628	SMD[b]	−0.65 (−1.04 to −0.25)	96.9%	.001
Psychoeducation with or without peer support[a]	9	919	1067	SMD[b]	−0.15 (−0.22 to −0.06)	0.0%	.004
Psychotherapy	19	2026	2357	SMD[b]	−0.87 (−1.26 to −0.48)	96.2%	<.001
Score on postpartum anxiety scale[a]	17	1010	1095	SMD[b]	−0.49 (−0.72 to −0.25)	84.6%	<.001
Higher quality[a]	12	788	857	SMD[b]	−0.49 (−0.81 to −0.17)	88.9%	.003
Lower quality	5	241	260	SMD[b]	−0.49 (−0.67 to −0.31)	0.0%	<.001
Developed country[a]	13	637	732	SMD[b]	−0.53 (−0.79 to −0.27)	79.4%	<.001
Developing country	4	392	385	SMD[b]	−0.37 (−0.87 to 0.13)	89.6%	.15
Online/web-based intervention	9	486	585	SMD[b]	−0.64 (−0.97 to −0.31)	82.9%	<.001
Smartphone application	6	469	462	SMD[b]	−0.38 (−0.74 to −0.03)	83.7%	.035
Text-message[a]	2	74	70	SMD[b]	−0.13 (−0.45 to 0.20)	0.0%	.44
Screen-positive for depression or anxiety	10	520	552	SMD[b]	−0.48 (−0.65 to −0.31)	38.7%	<.001
Screen-negative or no screening[a]	7	509	565	SMD[b]	−0.51 (−1.02 to −0.00)	93.3%	.051
Psychoeducation with or without peer support[a]	6	449	447	SMD[b]	−0.29 (−0.57 to 0.00)	68.33%	.052
Psychotherapy	11	580	670	SMD[b]	−0.60 (−0.91 to −0.30)	83.1%	<.001
Score on Edinburgh Postnatal Depression Scale[a]	22	2729	3193	WMD[c]	−0.64 (−0.92 to −0.35)	95.6%	<.001
Higher quality[a]	17	2556	3024	WMD[c]	−0.55 (−0.87 to −0.24)	99.31%	<.001
Lower quality	5	173	169	WMD[c]	−0.97 (−1.83 to −0.11)	94.94%	.027
Developed country[a]	18	2403	2873	WMD[c]	−0.58 (−0.89 to −0.27)	95.7%	<.001
Developing country	4	326	320	WMD[c]	−0.97 (−2.03 to 0.10)	95.6%	.07

Lewkowitz. Digital health interventions and postpartum depression or anxiety: meta-analysis. Am J Obstet Gynecol 2024. *(continued)*

TABLE 2
Pooled and stratified analyses of the effect of digital health interventions vs treatment as usual on postpartum depression or postpartum anxiety *(continued)*

Outcome	Number of studies[a]	Digital health intervention (n)	Treatment as usual (n)	Measure of effect	Effect size (95% confidence interval)	I^2	*P* value from DHI vs TAU
Online/web-based intervention	13	1144	1447	WMD[c]	−0.78 (−1.29 to −0.28)	96.9%	.002
Smartphone application	7	1511	1676	WMD[c]	−0.51 (−0.87 to −0.15)	99.56%	.005
Text-message[a]	2	74	70	WMD[c]	−0.03 (−0.40 to 0.34)	22.4%	.88
Screen-positive for depression or anxiety	10	554	594	WMD[c]	−0.61 (−1.01 to −0.22)	89.8%	.002
Screen-negative or no screening[a]	12	2175	2599	WMD[c]	−0.66 (−1.07 to −0.24)	97.1%	.002
Psychoeducation with or without peer support[a]	10	984	1149	WMD[c]	−0.13 (−0.22 to −0.04)	3.7%	.04
Psychotherapy	11	1727	2026	WMD[c]	−1.07 (−1.66 to −0.49)	97.6%	<.001
Score on Generalized Anxiety Disorder-7 scale	6	364	384	WMD[c]	−0.52 (−0.78 to −0.25)	59.52%	<.001
Higher quality	5	356	363	WMD[c]	−0.53 (−0.81 to −0.26)	66.9%	<.001
Lower quality	1	8	21	WMD[c]	−0.37 (−1.19 to 0.45)	n/a	.38
Developed country	4	260	294	WMD[c]	−0.56 (−0.73 to −0.39)	0.0%	<.001
Developing country	2	104	90	WMD[c]	−0.41 (−1.32 to 0.51)	87.27%	.38
Online/web-based intervention	4	260	294	WMD[c]	−0.56 (−0.73 to −0.39)	0.0%	<.001
Smartphone application	2	104	90	WMD[c]	−0.41 (−1.32 to 0.51)	87.27%	.38
Text-message	0	–	–	WMD[c]	–	–	–
Screen-positive for depression or anxiety	6	364	384	WMD[c]	−0.52 (−0.78 to −0.25)	59.52%	<.001
Screen-negative or no screening	0	–	–	WMD[c]	–	–	–
Psychoeducation with or without peer support[a]	1	37	34	WMD[c]	−0.51 (−0.83 to −0.20)	67.3%	.035
Psychotherapy	5	327	350	WMD[c]	−0.51 (−0.98 to −0.04)	—	.01
Did not finish last study assessment (n)[a]	32	1811	1374	RR[d]	1.38 (1.18–1.62)	72.4%	<.001
Higher quality[a]	21	1676	1271	RR[d]	1.44 (1.19–1.74)	77.7%	<.001
Lower quality	11	135	103	RR[d]	1.22 (0.89–1.66)	47.6%	.21
Developed country[a]	25	1654	1212	RR[d]	1.51 (1.26–1.80)	75.1%	<.001
Developing country	7	157	162	RR[d]	0.97 (0.81–1.17)	0.0%	.76
Online/web-based intervention	19	769	426	RR[d]	1.77 (1.46–2.15)	57.4	<.001
Smartphone application	11	1033	930	RR[d]	1.04 (0.91–1.19)	25.5%	.39
Text-message[a]	2	9	18	RR[d]	0.55 (0.23–1.33)	25.6%	.19
Screen-positive for depression or anxiety	17	288	177	RR[d]	1.47 (1.11–1.94)	60.5%	.008
Screen-negative or no screening[a]	15	1523	1197	RR[d]	1.34 (1.09–1.64)	80.8%	.005

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TABLE 2
Pooled and stratified analyses of the effect of digital health interventions vs treatment as usual on postpartum depression or postpartum anxiety *(continued)*

Outcome	Number of studies[a]	Digital health intervention (n)	Treatment as usual (n)	Measure of effect	Effect size (95% confidence interval)	I^2	*P* value from DHI vs TAU
Psychoeducation with or without peer support[a]	12	487	375	RR[d]	1.14 (0.87−1.50)	58.3%	.32
Psychotherapy	20	1322	997	RR[d]	1.52 (1.22−1.90)	78.4%	<.001

DHI, digital health intervention; *RR*, relative risk; *SMD*, standardized mean difference; *TAU*, treatment as usual; *WMD*, weighted mean difference.

[a] Dol et al[21] study counted as 2 studies; [b] Calculated via Hedge g statistic; [c] Calculated via pooled mean difference; [d] Numbers >1=loss to follow-up is greater among DHIs compared with TAU.

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heterogeneity, particularly for study intervention. Indeed, a trial analyzing the effect of self-guided online videos on CBT[45] and another trial analyzing the effect of a live, interactive, remote CBT workshop[60] were both categorized as a DHI offering online CBT, although these interventions clearly differed. Reframing the heterogeneity of DHIs included in this meta-analysis as mirroring differences between in-person CBT, IPT, or mindfulness programs also reduces the potential effect of heterogeneity on our outcomes. Specifically, each psychotherapeutic intervention abides by defined principles within CBT, IPT, or mindfulness, but is not identical to other programs offering the same psychotherapy. Third, the varying definitions of screening positive for PPD or PPA and the paucity of studies that included data on screening positive for either condition limited our ability to examine the effect of DHIs on screen-positive PPD or PPA. Lastly, there was also marked heterogeneity in psychometric scales used in the primary PPD and PPA outcomes. Given that our secondary outcomes were scores on one PPD or PPA scale and that these analyses had results similar to those from our primary analysis, it is unlikely that this heterogeneity affected our results.

Need for additional research

The fact that participants were more likely to not complete final study assessments if randomized to the DHI group compared with the TAU group demonstrates that more research is needed to optimize acceptability and use of DHIs in clinical settings. Incorporating end-user feedback into the intervention development process has been described as an effective strategy to encourage sustained participant engagement with DHIs.[69−71] In addition, the notable difference in LTFU rates between online DHIs and app-based DHIs—and in particular the lack of difference in LTFU rates between app-based DHIs and TAU—should be a research priority. Implementation research or hybrid implementation-effectiveness trials may offer another avenue to understand and optimize DHI use.[72] Lastly, most included studies assessed PPD, but fewer assessed PPA. Future research on DHIs should include assessments for both PPD and PPA.

Conclusions

The results from this meta-analysis of randomized trials suggest that DHIs significantly—although modestly—DHIs reduce PPD and PPA symptoms, and that this effect is more pronounced if the DHI delivers psychotherapy such as CBT, IPT, or mindfulness. Although LTFU rates were higher overall among those randomized to DHIs than those randomized to TAU, there was no difference in LTFU rates between those randomized to apps and TAU. These findings suggest that DHIs that provide psychotherapy and are delivered via smartphone applications may be the most effective at improving perinatal psychological outcomes and retaining participant engagement. However, because few studies include app-based psychotherapy, additional high-quality randomized trials are needed to further examine the potential of DHIs delivering psychotherapy via a smartphone application, specifically in reducing PPD and PPA. ■

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