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Effect of technology-supported mindfulness-based interventions for maternal depression: a systematic review and meta-analysis with implementation perspectives for resource-limited settings

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Abstract

Background Maternal depression is pregnancy and childbirth-related depression during pregnancy (prenatal depression (PND)) or after delivery (postpartum depression (PPD)). It is a recognized global public health concern with extensive repercussions adversely affecting women's well-being and the developmental progress of infants. Mindfulness-based interventions (MBIs) have been shown to be effective in maternal depression. Technology-supported MBI could be an effective preventive strategy for maternal depression, especially in low- and middle-income countries (LMICs) where lack of important resources limits the accessibility to standard care. However, the limited available studies assessing the effect of technology-supported MBIs for maternal depression might be insufficient to reach a definitive conclusion. This systematic review aimed to evaluate the pooled estimated effect of technology-supported MBIs for maternal depression, identify available studies, and reveal applicable health technologies with MBIs.

Method This study was conducted according to the PRISMA-P 2020 and the review protocol was registered in PROSPERO; CRD42024537853. The risk of bias was evaluated using the PEDro scale. The meta-analysis was done with R.

Result Data from 18 articles, none from low-income countries (LICs), were included in the systematic review, representing 2,481 participants, 15 studies were included in the meta-analysis. The pooled effect size indicated that technology-supported MBIs had a positive effect on maternal depression (SMD −0.55, 95% CI [−0.70; −0.40], $p < 0.001$). The sub-group analysis showed that this intervention was effective in both PND (SMD = −0.57, 95% CI [−0.74; −0.39], $p < 0.001$) and PPD (SMD −0.53, 95% CI [−0.91; −0.15], $p = 0.014$).

Conclusion Integrating technology-supported MBIs into maternal care is recommended to enhance maternal mental health. However, the lack of trials in LMICs may limit the generalizability and external validity of this finding

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and it is crucial to conduct further research, in the area to tailor intervention and maximize its effectiveness. Context-specific trial studies are pivotal for successful program adoption.

Keywords Maternal depression, Meta-analysis, Mindfulness-based interventions, Perinatal depression, Prenatal depression, Postpartum depression, Systematic review, Technology

Background

Maternal depression is a pregnancy and childbirth-related depression. It can happen during the pregnancy, known as prenatal depression (PND), or after delivery which is referred to as postpartum depression (PPD) [1–3]. It is recognized globally as a significant public health concern with extensive repercussions that can adversely affect women's well-being and developmental progress of the infant born to those women [4, 5].

A recent review indeed estimated an overall mean prevalence of maternal depression of 26.3%, whereas the PND and PPD were 28.5% and 27.6% respectively [6]. Furthermore, another recent systematic review and meta-analysis highlight the fact that these conditions are highly prevalent in low- and middle-income countries (LMICs) where the pooled prevalence of maternal depression was estimated at 23% [7] with the high probability of this prevalence is underestimated due to lack of awareness and means to detect maternal depression in LMICs. Evidence showed that there is a restraint of screening tools for depression yielding extremely low detection of this disease and posing a serious threat to mental healthcare scaling up [8].

PND and PPD are interdependent maternal health problems that need critical consideration, and the case becomes more prevalent when the time progresses from the early pregnancy period to post-delivery time. Accordingly, the prenatal and postpartum phases are critical for the immediate and extended health outcomes and welfare of both the mother and neonate. Prompt and targeted interventions are therefore essential to enhance maternal mental health, with a particular emphasis on PND as the timing of its onset significantly affects maternal care and associated symptoms [9].

Different interventions, including anti-depressant medication and psychological therapies, and other non-pharmacological approaches such as mindfulness-based interventions (MBIs), have yielded inconsistent results in treating maternal depression. Some trial studies found no significant effect of the intervention; others reported a moderate impact on maternal depression. This discrepancy poses a scientific challenge in concluding the overall effectiveness of MBIs for maternal depression [10–12].

Mindfulness represents a heightened state of consciousness, characterized by the deliberate focus on the immediate experience. It is cultivated through an intentional and non-evaluative engagement with the present moment, fostering an attitude of acceptance and openness [13]. The scope of MBIs has expanded from traditional definitions to include enhanced meditation practices like Mindfulness-Based Cognitive Therapy [13], stimulus control and sleep restriction [14], progressive muscle relaxation meditation [15], mindfulness-based cognitive reconstruction [16], mindfulness-based sleep intervention; involving, sleep education, sleep hygiene, stimulus control, and cognitive restructuring [17], and other various activities [18]. Thus, MBIs encompass a range of mind-body practices and traditional mindfulness practices without the physical component where the key concept in both practices is "present-moment awareness" [16]. The mindfulness process was derived from the practice of the Buddhist religion and Philosophy that the ancient community was using for the cessation of personal suffering. Nowadays, it is being used as an intervention practice for bringing a certain quality of attention to moment-by-moment so that it helps to mediate the alleviation of different psychological morbidities including depression [19, 20].

Trial studies evaluating the effectiveness of MBIs confirmed that it is cost-effective and efficient to improve the patient status of depression, anxiety, stress, insomnia, addiction, psychosis, and prosocial behaviors in different settings like healthcare settings, schools, and workplaces [21]. Consistently, there are different MBIs used for mental health conditions in pregnant women. The pooled effect evidence denoted that MBI has decreased PND in pregnant women without pre-existing disorders [22]. Additionally, other meta-analyses point out that MBI has some effect on mental health outcomes in pregnant women [23].

Despite the availability of these systematic reviews and meta-analyses, it is important to note that evidence from trial studies conducted in LMICs is still scarce [24]. Moreover, while MBIs have shown promise in addressing maternal depression, their implementation in LMICs faces unique challenges. Traditional MBIs, typically delivered in-person, may be particularly difficult to implement in resource-limited settings due to, for example, a shortage of trained mental health professionals; geographical barriers to accessing care; limited healthcare infrastructure; and cost constraints [24]. Hence, this systematic review aimed at evaluating the pooled effect of not only MBIs alone for maternal depression but is supported by the technology because a systematic review and meta-analyses indicated that health technology employing RCT studies are scarce from LMICs where the majority

of the studies were conducted in high-income countries [25].

Health mediations such as MBIs are more joyful, adherable, and long-lasting treatment and preventive strategies for maternal depression when supported with technology [26, 27]. According to the World Health Organisation (WHO) definition, "Health technology is the application of organized knowledge and skills in the form of devices, medicines, vaccines, procedures, and systems developed to solve a health problem and improve quality of life (QoL)". It encompasses a broad concept that includes drugs, devices, procedures, and processes of organizational approach. Health technology has attributes to the intervention that is developed to prevent, diagnose, or treat medical conditions, promote health, provide rehabilitation, improve the organization of healthcare delivery, or provide useful information that can aid in making informed decisions to promote a health system that is equitable, efficient, and of high quality everywhere to everyone [28, 29].

Emerging evidence suggests that health technology offers benefits to mental health and advances in mental health support [30–32]. It is effective in psychotherapy to improve mood, sleep, and social support [31, 33]. Patients who received additional treatment using technology for example, an online mindfulness-based cognitive treatment showed greater reductions in depressive symptoms, presented higher rates of remission, and improved QoL compared to those who received usual care only [34, 35]. Furthermore, technology-supported health services such as internet-based mental health interventions offer the advantages of accessibility, cost-effectiveness, and anonymity to the individual [27, 36]. Consequently, it has become promising that health technology interventions work in the treatment of mental health conditions related to pregnancy and childbirth like maternal depression [37, 38].

Convincingly, the effect of the combination of these interventions (health technology and MBIs) has gained popularity for maternal depression. A pre-post-study conducted among pregnant women showed that mobile health application-based mindfulness efficiently reduced PPD symptoms [39]. An RCT found that mindfulness training through smartphones effectively reduced maternal depression in early pregnancy for women who are at risk [40].

However, despite the high prevalence of maternal depression in LMICs, there is limited research on technology-supported MBIs in these settings. This is particularly concerning given that LMICs face unique challenges, including limited technological infrastructure, digital literacy barriers, cultural appropriateness, and resource constraints in implementing digital health interventions. Consequently, there is a pressing need for a thorough review and synthesis of the literature before developing and assessing interventions to reduce and prevent maternal depression in LMICs [41].

While previous systematic reviews and meta-analyses have reported positive findings [42, 43] the present review offers several key advancements. It incorporates a broader range of technologies, consistent with the WHO definition, allowing for a more comprehensive synthesis of data from various RCTs. This inclusivity strengthens the evidence base by minimizing potential bias and providing a more complete understanding of intervention effectiveness. Furthermore, the inclusion of recently published studies increases the overall sample size and statistical power, improving the ability to detect the effects of technology-supported MBIs for maternal depression. Finally, this review addresses a critical gap by examining research needs in resource-limited settings and exploring the potential benefits of technology in these underserved contexts.

Therefore, the purpose of this systematic review and meta-analysis was to evaluate the efficacy of technology-supported MBIs for maternal depression, identify available studies, and reveal applicable health technologies with MBIs, covering both PND and PPD.

Methods

Search strategy

This systematic review and meta-analysis was conducted according to the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2020 statement [44]. The protocol for the review was registered in PROSPERO (CRD42024537853).

The literature search was performed on four databases: PubMed, Web of Science, Scopus, and PsycINFO using the search terms "(Mindful* OR meditat* OR meditation OR mindfulness-based interventions OR MBIs) AND (prenatal OR antenatal OR pregnan* OR postnatal OR postpartum OR post delivery OR postpartum period) AND (depress* OR depression OR depressed OR depressive) AND (virtual reality OR mobile health OR mHealth OR digital health OR VR OR serious games OR app* OR eHealth OR smartphone* OR internet OR computer*)" that developed using keywords, synonyms, and MeSH terms in the PubMed database and rearranged according to the specific databases.

The primary and review articles' references were cross-referenced to ensure the inclusion of all relevant articles. Only peer-reviewed articles published in English were analyzed. Articles were restricted to studies published in English exclusively considering the language proficiency of the researchers who conducted this systematic review and meta-analysis. It was to ensure uniformity in data extraction and analysis, consistency in interpretation, and to minimize the introduction of bias due to the

language barrier. All studies published before 30/05/2024 were considered.

Research selection

The inclusion criteria for the articles depended on the Patient, Intervention, Comparison, Outcome, and Study design (PICOs) (Table 1). Articles were screened and selected by two reviewers independently (B.T.W and M.A). Discrepancies were resolved through discussion or consultation with a third reviewer (D.A).

Quality assessment

The risk of bias in the included studies was assessed with the PEDro scale. The strength of the PEDro scale lies in its comprehensive criteria for quality assessment, specifically designed for RCTs only, making it highly suitable to use in this systematic review study. Furthermore, this scale provides a clear structured format that is not complex to apply while it is comprehensive enough. The PEDro scale has 11 items scale, and each satisfied item contributes one point to the total PEDro score. Item one is omitted for score calculation so that the score ranges from zero to ten points. Total PEDro scale scores of zero to three are considered 'poor quality', four to five 'moderate quality', and six to ten 'good quality' for each RCT study, and this category was used in this study [45–47]. To rate the overall quality of evidence of each outcome, the GRADE approach was used [48].

Data extraction

The following information was extracted from the included studies: number of participants, maternal age, maternal stage for when the depression was considered (PND or PPD), maternity period (gestational age in weeks or postpartum period in weeks), length of intervention in week, number of sessions per week, length of the sessions in minutes, aim of the intervention either depression prevention or treatment, type of the applied technology, summary of the intervention description, depression measurement scale, main results, and country where the study was conducted.

Table 1 Inclusion criteria for the articles for the systematic review

PICOs	Criteria
Population	- Pregnant women with or without prenatal depression - Postpartum women with or without postpartum depression
Intervention	- MBIs supported with any type of technology
Comparison	- Conventional care, or - MBIs alone (delivered without support with any technology), or - No intervention
Outcome	- Maternal depression
Study Design	- RCTs

Data analysis

The potential pooled effect of the technology-supported MBIs for maternal depression was examined with meta-analysis. The measure of treatment effect was the standardized mean difference effect size (standardized mean difference (SMD)), defined as the between-group difference in mean values divided by the pooled SD computed using the Hedge's g method. A negative SMD implies a decreased depression level in the intervention group compared to the control. We assessed the heterogeneity in stratified analyses by type of depression. We calculated the variance estimate tau^2 as a measure of between-trial heterogeneity. We pre-specified a tau^2 of 0.0 to represent no heterogeneity, 0.0–0.2 to represent low heterogeneity, 0.2–0.4 to represent moderate heterogeneity, and above 0.4 to represent high heterogeneity between trials [49]. To deal with high or moderate heterogeneity we used random-effect models and presented forest plots for both PND and PPD. We checked for publication bias using a funnel plot [50] and Egger's test for the intercept was applied to check the asymmetry [51]. Random-effects meta-regression analysis quantified the association of changes in cognitive functions and the amount of training and the age of the participants. Studies were weighted by the inverse of the sum of the within- and between-study variance [52].

Statistical analyses were performed at an overall significance level of 0.05, carried out in R.

Results

Characteristics of the study

Three hundred and seventy-three articles were retrieved from the four selected databases. Eight more articles were detected through manual searching. Sixty-two articles were removed for duplication. Three hundred and nineteen articles were screened with their title and abstracts among which 299 were excluded for not fulfilling the PICOs criteria of this systematic review. Twenty studies were screened with full article reading and two of them were excluded for duplication and for not fulfilling the inclusion criteria. Finally, a total of 18 articles were included in the systematic review, and fifteen data sources were included in the meta-analysis, the complete flow of study selection is presented in Fig. 1.

The 18 included studies represented a total of 2,481 participants with a mean age of 31.18 ± 6.78 years.

Most of the included studies ($n = 11$) were conducted among pregnant women for PND [53–65], representing 2,133 participants, and some of these trials broadened their scope of outcome evaluation to the effect of the intervention in postpartum women. Three

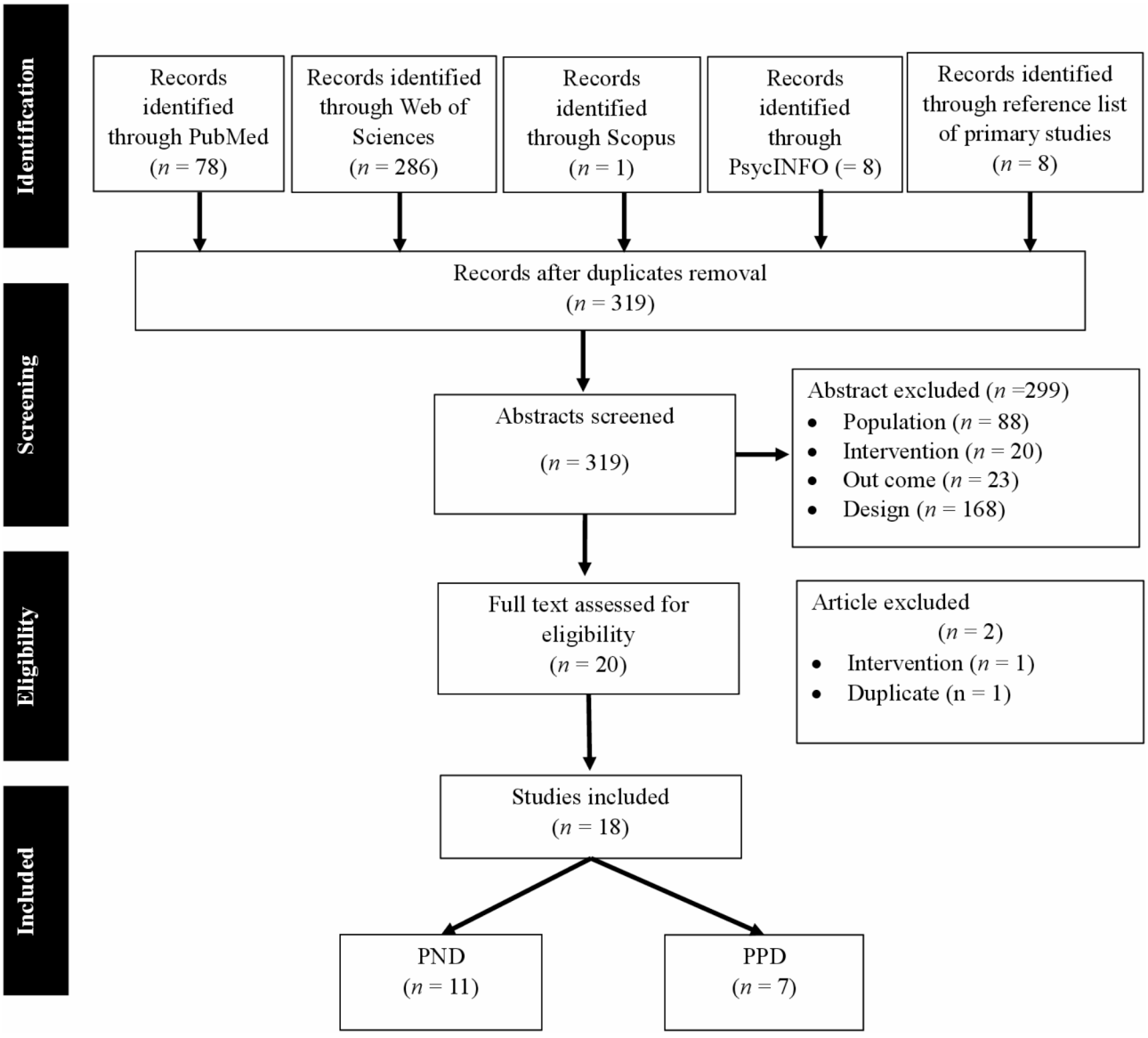

Fig. 1 PRISMA flow chart of study selection

studies conducted the intervention among the postpartum women [39, 66, 67]. Of the 18 articles included in the systematic review, four studies [68] described overlapping samples; one for different mindfulness intervention approaches with three arms [53] and three for different outcomes that included both PND and PPD [62, 68, 69].

The gestational age of the study participants among pregnant women was a minimum of 12–16 weeks [62] to a maximum of 36–38 weeks [39]. In all the studies, women experiencing their first pregnancy constituted a majority of the research sample sizes. The complete description of the individual studies is presented in Table 2.

Concerning the clinical evaluation, thirteen studies used the Edinburgh Postnatal Depression Scale (EPDS) to measure PND and PPD. Two studies used the Patient Health Questionnaire (PHQ-9) [53, 70], one study used the Depression Anxiety Stress Scale (DASS-42) [61], one study the Depression Anxiety and Stress Scale Short Form (DASS21) [71], and one study the Hamilton Depression Rating Scale (HDRS) [67].

The geographic distribution analysis revealed a significant disparity, with most studies conducted in high-income countries (Canada, Germany, New-Zealand, Australia, America, and Sweden), ten studies from upper-middle-income countries (China and Taiwan), only one from a lower-middle-income country, namely India [72], and notably no studies from LIC.

According to the PEDro scale out of ten scores for the assessment of the risk of bias for the individual studies

Table 2 Characteristics of the included studies

Author (Year)	Country	Sample size	Maternal age in year (Mean/SD)	Maternity stage. Week Mean/SD	Aim	Technology	Description of the intervention	Duration in week	Number session	Setting	Depression Scale	Main finding and conclusion	RoB
Yang et al. (2019) [70]	China	123	Above 18. (31.31/4.97 Intervention, 30.38/3.91 in control)	Prenatal. 24 to 30 (25.52/1.84 intervention and 26.33/3.45 control)	Therapy	Mobile application: Online Wechat platform	Intervention group shared sessions on WeChat with text, images, and audio related to the course. Control group got standard care	8	Mean/SD of 3.25 /1.45 per week	Hospital	PHQ-9	There was a notable decrease in symptoms of depression with the scores dropped in 41 intervention group women and 22 of the control group	7/10
MacKinnon et al. (2021) [54]	Canada	60	Over 18. (31.75/4.94)	Prenatal. Between 12–28 (20.83/4.92)	Therapy	Audio and video: As CD and DVD	Intervention given in lab by clinical psychologist and women took manual, CD for meditations guide and DVD with mindful demonstration. Controls group took routine care	8	Seven sessions were delivered per week	Hospital and Home	EPDS	The intervention was associated with improved overall psychological distress, but there was no difference in maternal depression specifically	8/10
Zhang et al. (2023) [88]	China	160	More than 18. (30.29/4.29)	Prenatal. From 12–20. (16.69/1.60)	Therapy	Smartphones or PCs based Digital	Intervention given on WeChat mini program. Women viewed animated videos including variety of cartoon images and demonstrations. Control group took usual prenatal care.	6	Seven sessions were delivered per week	Home	EPDS	Post-intervention PND and PPD were lower after the intervention to six weeks after delivery: Cohen d values of 0.56 and 0.84 respectively	8/10
Guo et al. (2020) [89]	China	284	18–40 years. (29.8/6.2 in control and 31.4/5.7 in intervention group)	Prenatal. Second or third trimester but before 34 weeks	Prevention	Web-based intervention	Instruction video given outline. Information on the technique introduced. Six sequential steps with different exercises with guided instructions were performed stepwise way.	6	Six episodes in a week.	Home	EPDS	Compared with the control group, the intervention group showed significant improvement in depressive symptoms.	6/10
Liu et al. (2022) [39]	China	130	25 to 40 (31.81/5.36)	Postpartum. Women recruited at 36–38 weeks	Prevention	Mobile health application (We'll App)	A four-component mindfulness and perceived social support interventions delivered for puerperae during childbirth. Control group received no intervention.	8	Three sessions were delivered per week	Home	EPDS	The intervention significantly reduced the subjects' levels of PPD symptoms.	8/10

Table 2 (continued)

Author (Year)	Country	Sample size	Maternal age in year (Mean/SD)	Maternity stage. Week Mean/SD	Aim	Technology	Description of the intervention	Duration in week	Number session	Setting	Depression Scale	Main finding and conclusion	RoB
Pan et al. (2019) [90]	Taiwan	74	At least 20. (32.8/3.9)	Prenatal. Between 13 and 28 (20.7/4.8)	Therapy	Audio record	Intervention given in a group once a week for eight consecutive weeks and practice 6 days per week for 30′ each day at home using recorded audio. Comparison group received a standard presentation on physiological and psychological information	8	Once a week in group and Six days per week at home	Home	EPDS	The depression score was significantly better (F = 7.36, p = 0.008) in the intervention group than comparison group at 3 months postpartum	8/10
Sun et al. (2021) [40]	China	168	18 and over. (29.91/4.015)	Prenatal. Between 12 and 20 (98.81/14.726 days)	Prevention	Smartphone (custom-built mobile app called Spirits Healing in Chinese)	Eight sessions: 1. Understand mindfulness; 2. Be in the present;3. Be mindful of negative emotions; 4 Accept difficulties; 5. Thoughts are just thoughts; 6. Enjoy daily happiness; 7. Mindful pregnancy and childbirth; and 8. Mindfulness practice continued. Control group took regular WeChat health consultation	8	Intervention was given seven days per week	Home	EPDS	Medium between-group effect size was found on depression and positive affect at post-intervention (Cohen d = 0.47, − 0.49).	8/10
Hassdenteufel et al. (2023) [60]	German	460	18 or older. (32.6 /4.3)	Prenatal. Between 29 and 36 (21.2/4.3)	Therapy	Electronic intervention - Accesed via Apple iTunes & Google Play Store	Intervention group got supervised online intervention: psychoeducational and obstetrical mindfulness exercises, cognitive behavioral approaches. Control group received treatment as usual	8	Weekly sessions were delivered	Hospital	EPDS	There was no significant interaction effect for depressive symptoms both during pregnancy and the postpartum period.	5/10

Table 2 (continued)

Author (Year)	Country	Sample size	Maternal age in year (Mean/SD)	Maternity stage. Week Mean/SD	Aim	Technology	Description of the intervention	Duration in week	Number session	Setting	Depression Scale	Main finding and conclusion	RoB
Nadholta et al. (2023) [61]	India	77	Between 18 and 35 (Mean/SEM 29.31/3.415)	Prenatal 16th to 20th week	Prevention	Online Google Meet	Gestational Yoga consisting of two protocols for 2nd and 3rd trimesters with stretching, breathing, relaxation, and meditation. All the sessions were delivered online by instructors. Control: took routine care.	16	5 days/week	Home	DASS-42	Depression significantly increased (7.33 ± 0.938 to 10.35 ± 1.191 ($p = 0.016$) in the control group and decreased (8.71 ± 1.441 to 4.41 ± 0.998 ($p = 0.000$) in the intervention group	7/10
Bear et al. (2022) [66]	New Zealand and Australia	99	Age range of 21–45 (31.16/4.83)	Postpartum. Mothers of children aged 0–12 months were included	Therapy	Smartphone application (Smiling Mind Application)	Women in Smiling Mind condition used the 'Mindfulness Foundations' programme which covers, the Breath, Sound, Taste, Thoughts, motions, Everyday Mindfulness, Curiosity, and Beginner's Mind, Stress, Sleep and Gratitude, Relationships and Mindful Listening. Control group used Baby + Tracker.	8	41sessions till the end	Home	DASS21	The intervention group showed significant decreases in depression compared to the control group.	5/10
Leng et al. (2023) [62]	China	75	18 and above. (30.6/3.1)	Prenatal. From 12–16 (18.8/4.6)	Therapy	App teaching module	Intervention group took 4 meditations: loving-kindness, compassion, appreciative joy, equanimity meditations. Control: attended web-based perinatal education.	8	Weekly group sharing and daily at home	Home	EPDS	The intervention was effective in reducing depression. Women in the intervention group showed a greater reduction in depression (adjusted mean change difference [β] = -3.9; 95% CI = (-6.05, -1.81); d = -0.6)	7/10

Table 2 (continued)

Author (Year)	Country	Sample size	Maternal age in year (Mean/SD)	Maternity stage. Week Mean/SD	Aim	Technology	Description of the intervention	Duration in week	Number session	Setting	Depression Scale	Main finding and conclusion	RoB
Yang et al. (2022) [53]	China	108	≥ 18 -	Prenatal. < 32 weeks of gestational age	Therapy	Computer or smartphone based WeChat platform	Mindfulness training conducted online. Monitoring training was used to foster an ongoing awareness of momentary experiences and contained the skill of concentration. Control: got emotion regulation course.	4	Four sessions in a week	Home	PHQ-9	No significant difference was observed: (Mdiff = 0.648, SE = 0.895, p = 0.471) or GAD-7 (Mdiff = 1.406, SE = 1.065, p = 0.192) scores.	9/10
Zhang et al. (2023) [55]	China	108	From 21 to 42 (28.85/3.60)	Prenatal. Weeks from 12–24 (18.70 /5.65)	Therapy	WeChat messaging app: Audio file sent over the WeChat	Intervention group involved in mindfulness courses and practices. They listen to a program-related audio file sent over WeChat. Control: took health education	4	The session was seven days per week	Home	EPDS	The GEE analysis showed the significant main effect of intervention in the group (Wald X2 = 5.00, p = 0.005) depression.	9/10
Pan et al. (2019) [57]	Taiwan	96	At least 20. (32.83/3.83)	Prenatal. Between 13 and 28 weeks	Therapy	Audio recordings	The intervention programme provides a series of nine three-hour classes a week and one seven-hour day of silent-meditation practice. Also, the participants listen to programme-related audio recordings at home. Comparison: took conventional child- birth education	8	Six days per week	Home	EPDS	The intervention effectively reduced self-perceived depression. The mean score for the experimental group was 2.56 points lower than that for the comparison group ($p < 0.001$) at post-intervention.	7/10
Kalmbach et al. (2020) [64]	USA	91	Mean/SD age of the women was 29.03/4.16	Prenatal. (27.76/0.87)	Therapy	Internet-based digital therapy	The Intervention covered behavioral components (sleep restriction, stimulus control), cognitive components (cognitive restructuring, paradoxical intention), progressive muscle relaxation, and sleep hygiene. Control: got digital sleep education.	6	(M ± SD) 5.14 ± 1.75 5.47 ± 1.58 in control 4.83 ± 1.88 in intervention	Hospital	EPDS	Post-treatment depression symptom scores did not differ between intervention and control groups	7/10

Table 2 (continued)

Author (Year)	Country	Sample size	Maternal age in year (Mean/SD)	Maternity stage. Week Mean/SD	Aim	Technology	Description of the intervention	Duration in week	Number session	Setting	Depression Scale	Main finding and conclusion	RoB
Doty et al. (2022) [91]	America	56	At least 18 years old aged were included	Prenatal. Pregnancy of 23–32 weeks were included	Therapy	Audio and Calm phone application, and an audio recording	Intervention delivered with step: 1. verbal introduction, 2. Written information, 3. Audio recording 4. The Calm phone application set up, and 5. Subsequent meditations.	4 days	Two times per day	Hospital	EPS	Depression symptom scores had no differences after the intervention: the change level was − 1.0(± 4.0) in control and − 1.9 (± 2.6) in intervention	8/10
Buttner et al. (2015) [67]	USA	56	From 18 to 45. (29.81/5.17 in case and 32.45/4.78 in control	Postpartum. 48 weeks postpartum	Therapy	DVD	A Gentle Vinyasa Flow class was for yoga intervention supported with a yoga practice at home using DVD. Control: Asked to refrain from practicing yoga.	8	Three days per week in general	Home and Facility	HDRS	The intervention showed empirical support for PPD treatment. The symptoms decreased over time ($t = -10.17$; $df = 55$; $p < 0.001$)	8/10
Lönnberg et al. (2021) [68]	Sweden	193	At least 18. (32/3.86) in case and (32/4.14) in control)	Prenatal. Between 19 and 26 weeks	Therapy	Audio files	Intervention consisted of group-based sessions during antenatal education and home-based formal practice with audio	8	Seven days per week	Home and facility	EPDS	In prenatal both groups significantly decreased their depression scores from baseline to post-intervention ($F = 15.12$, $p < 0.001$), larger decrease in intervention group. From post-intervention to 12 months postpartum, there was no significant change ($F = 0.57$, $p = 0.63$).	6/10

EPDS (Edinburgh Postnatal Depression Scale), DASS-42 (Depression Anxiety Stress Scale), DASS21 (Depression Anxiety and Stress Scale Short Form), PHQ-9 (Patient Health Questionnaire), EDS (Edinburgh Depression, HDRS (The Hamilton Depression Rating Scale Scale)

included in the systematic review, two articles had moderate quality [4–5] and the remaining had good quality [46] (Fig. 2).

Characteristics of the intervention

Various MBI techniques were utilized for the intervention. The studies incorporated in this systematic review generally focused on the mindfulness exercises that includes "paying attention to the intended target and discriminating present experiences, helping women change their relationship to thoughts, guiding women to recognize and disengage from unhelpful and ruminative thought patterns, adopting an accepting attitude toward physical and emotional experiences, mindful breathing, body scan, mindfulness and compassion with self and others, how to monitor sensory and emotional states and cognitive processes, deepen sensory self-awareness, become mindful of the process of labour and parenting, mindful stretching, mindful meditation, pausing in the midst, sleep and gratitude, relationships and mindful listening, mindful eating, mindful walking, mindfulness exercises, physical postures, relaxation practices, sound and taste, curiosity and beginner's mind, thriving in pregnancy, label by feeling, thinking, hearing, seeing, tasting, and smelling, progressive muscle relaxation, and sleep hygiene, yoga intervention such as salutations, balancing, twisting and relaxation poses, sitting and walking meditation, and loving kindness meditation.

Majority of the studies used treatment as usual for the comparison group. In one study, the comparison group received a standard presentation on physiological and psychological information and practice skills during pregnancy and after birth [57]. In another trial, the control group received regular WeChat health consultations [40]. One of the articles indicated that the control group was using Baby + Tracker smartphone application which offers a combination of postpartum support and information, tracking infant progress, milestones, and daily routine, and capturing memorable moments [66]. In other trials, the control group took web-based perinatal education, an emotion regulation course, health education, conventional childbirth education, and digital sleep education [53, 55, 57, 62, 69], (see a complete description of the intervention in (Table 2).

The mean duration of the intervention was 7.28 ± 2.95 weeks, ranging from 1 [65] to 16 [61] weeks in pregnant women while it was eight [39] weeks for all interventions tried among the postpartum women.

A significant number of interventions across the included articles used mobile applications ($n = 10$); Online Wechat platform, Calm phone application setup, App teaching module, Smiling Mind Application, Google

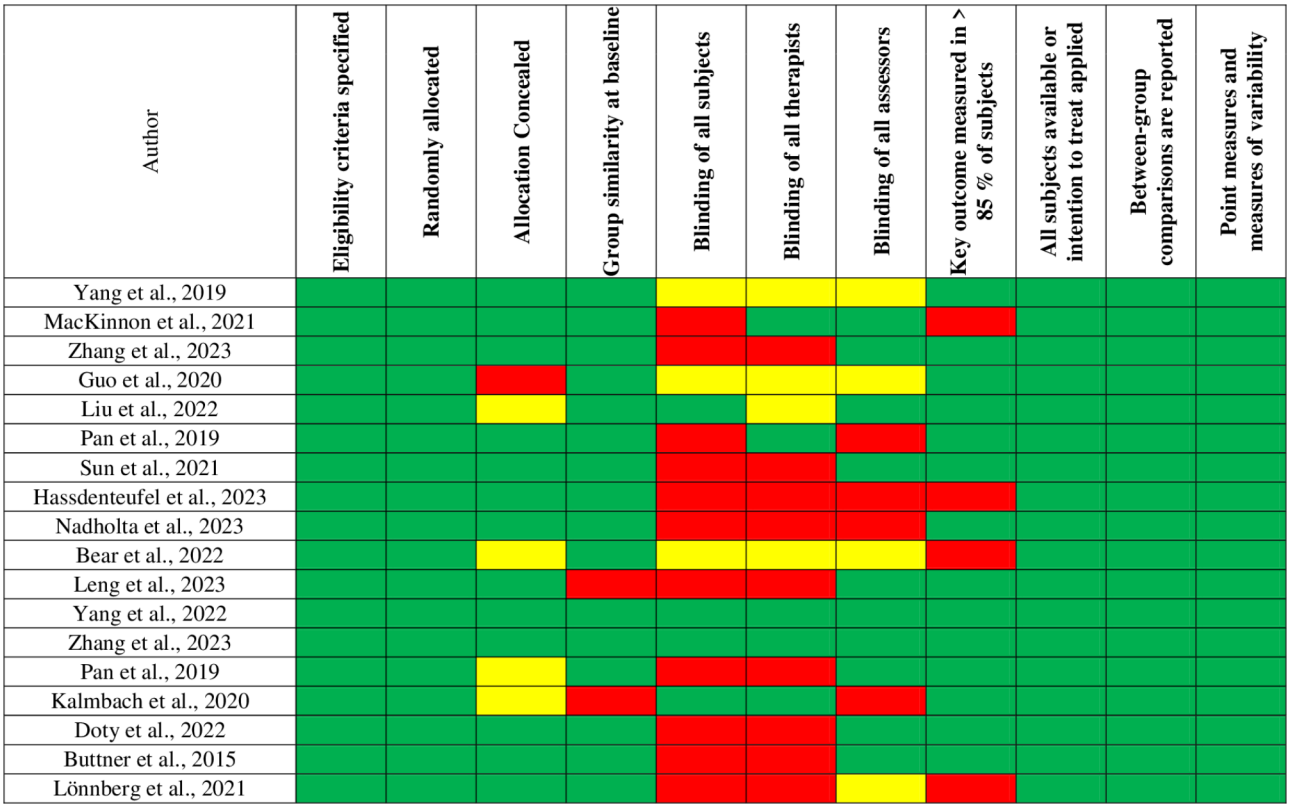

Fig. 2 PEDro analysis of the included articles. Green no risk of bias, yellow unclear and, and red risk of bias

Play Store, Spirits Healing in Chinese, and Mobile health application (We'll App) to deliver the MBIs. Other trial studies supported the intervention with audio and video recordings in Compact disc (CD) form for guided meditations and digital video disks (DVDs) that demonstrate mindful movement, and Internet-based digital therapy such as Online Google Meet (Fig. 3).

Clinical efficacy

The main results and conclusion of the individual included studies are presented in Table 2.

First, we performed a sensitivity analysis to detect potential outliers, no study was found to have an extreme effect on the results, the sensitivity analysis is presented in Supplementary Fig. 1.

We also checked for potential publication bias. We did not detect publication bias as the funnel plot did not show significant asymmetry (Egger's intercept = -1.64 (1.70), $p = 0.35$), see Supplementary Fig. 2.

The random effect model was applied to evaluate the clinical efficacy of the technology-supported MBIs for maternal depression, both PND and PPD since we found high heterogeneity between trials ($I^2 = 54\%$, $\tau^2 = 0.0513$, $p < 0.01$) [73]. Regarding the overall pooled effect estimates, the analysis result favoured the intervention indicating the positive effect of the technology-supported MBIs for maternal depression. The overall effect size (SMD −0.55, 95% CI [−0.70; −0.40], $p < 0.001$) showed a significant reduction of maternal depression symptoms in the intervention group as compared to the control group.

According to the findings of this investigation, the efficacy of the technology-supported MBIs remains consistent across both the prenatal and postpartum stages of maternal depression demonstrating no significant variance in the outcomes. The subgroup analysis for the category of PND and PPD suggested the effectiveness of the technology-supported MBIs for maternal depression. There was a substantial decrease in the PND (SMD −0.57, 95%CI [−0.74; −0.39], $p < 0.001$) and PPD (SMD −0.53, 95%CI [−0.91; −0.15], $p = 0.014$) as compared to the control group (Fig. 4).

We then performed meta-regression to determine if the amount of use (total number of sessions and the duration of the intervention) influences the outcome. We did not find a statistically significant association between the total amount of use and the clinical outcome (β = -0.0039, Standard Error [SE] = 0.0043, $p = 0.38$), nor for the total duration (in weeks) (β = -0.0345, SE = 0.0277, $p = 0.23$) (Fig. 5).

Finally, the overall quality of evidence of each outcome is explained in Table 3. For both PND and PPD, the level of evidence associated with technological MBI is moderate.

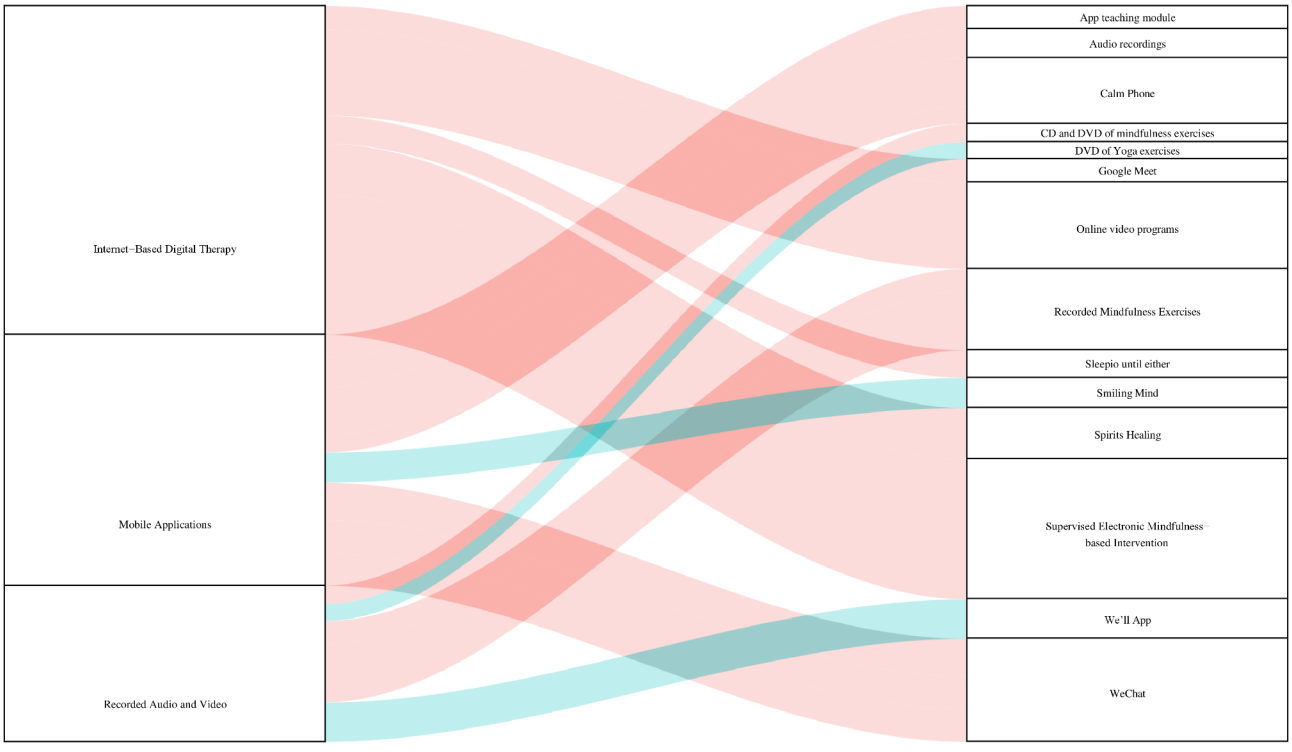

Fig. 3 Summarized types of used technology along with the type of maternal depression, red colour is used for PND and green colour for PPD

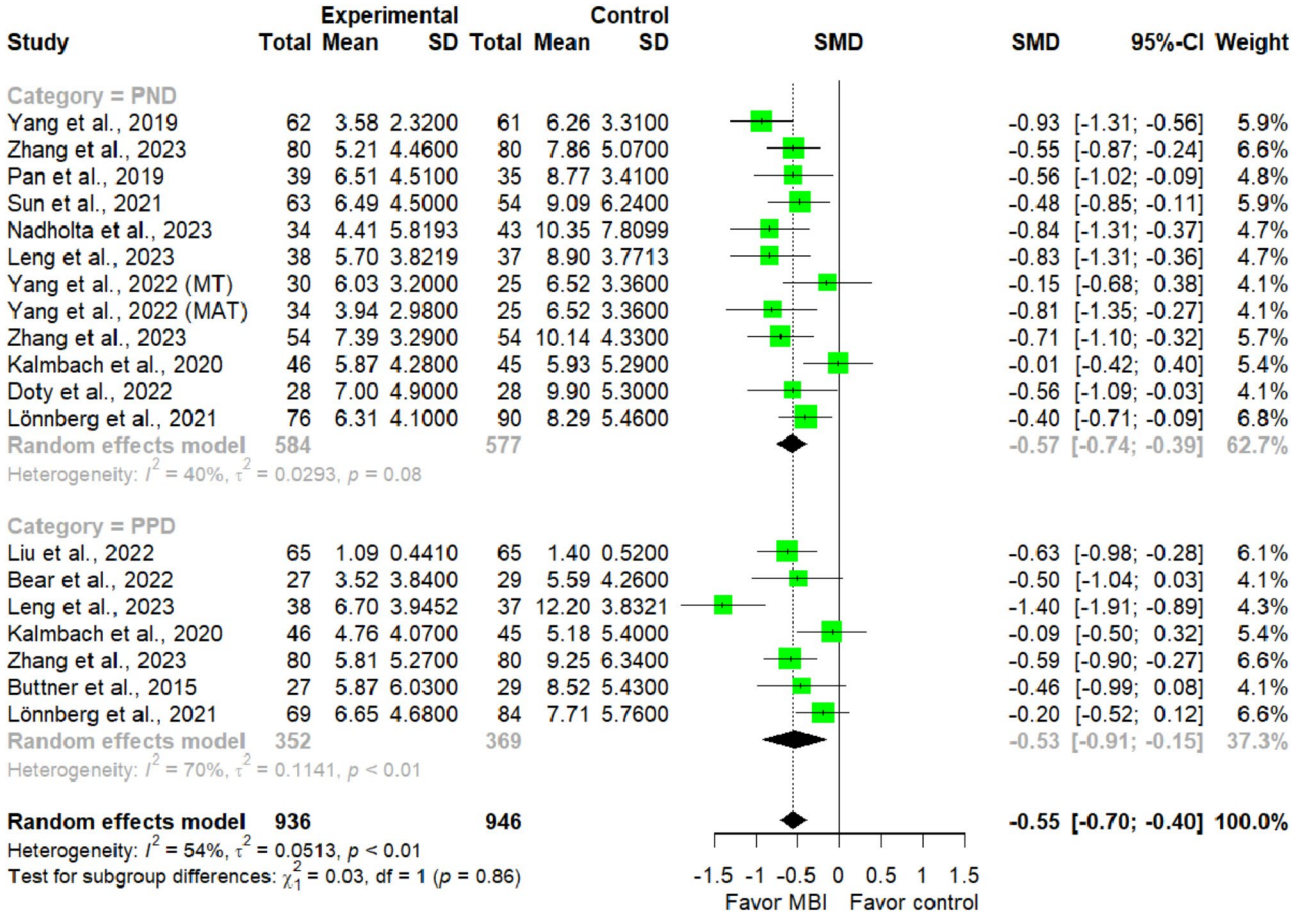

Fig. 4 Pooled results of the change in maternal depression drawn from the included RCTs. *MT (Monitoring training), MAT (Monitoring with an emphasis on acceptance training). MT and MAT are the two theoretical constructions that the mindfulness training programs were based on*

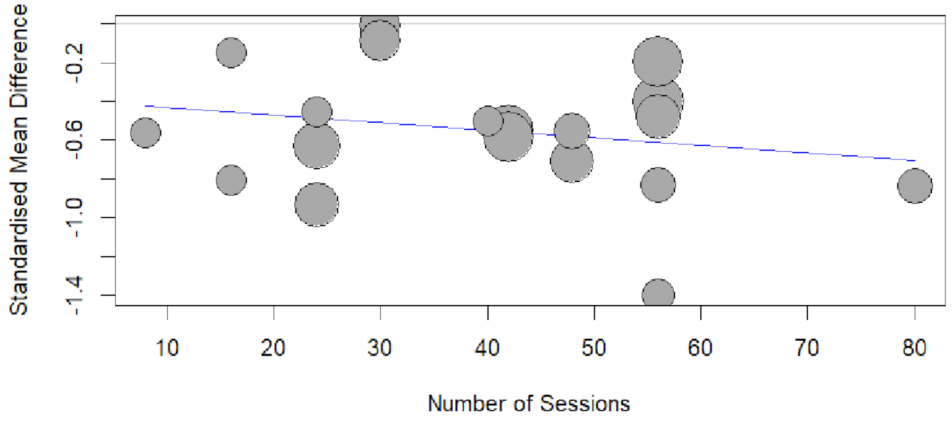

Fig. 5 Bubble plot showing the relationship between the total number of sessions and the effect on depression for all the included studies. The size is proportion to the study weight

Discussion

The objective of this systematic review and meta-analysis was to investigate the effect of technology-supported MBIs to enhance the mental health of pregnant and postpartum women specifically on alleviating PND and PPD symptoms. Our results indicated that maternal depression decreased substantially after the technology-supported MBI in comparison with the control group (SMD = -0.55, 95% CI [-0.70; -0.40], $p < 0.01$). These results are in line with the results of a previous meta-analysis that

Table 3 Quality of evidence– GRADE approach

Type	Participants and Results [95% CI]	Study limitations (0, -1, -2)	Imprecision (0, -1, -2)	Inconsistency of results (0, -1, -2)	Indirectness of evidence (0, -1, -2)	Publication bias (0, -1)	Certainty of the evidence
PND	12 RCTs ($n = 1161$) SMD – 0.57 (-0.74 to -0.39)	Some concerns (-1)	No concerns (0)	No concerns (0)	No concerns (0)	No concerns (0)	Moderate[1]
PPD	7 RCTs ($n = 721$) SMD – 0.53 (-0.70 to -0.40)	Some concerns (-1)	No concerns (0)	Some concerns (-1)	No concerns (0)	No concerns (0)	Moderate[2]

Reasons for downgrading:

[1] Downgraded by one level due to some concerns about the risk of bias (average score on the PEDro scale is 7.3)

[2] Downgraded by one level due to some concerns about the risk of bias (average score on the PEDro scale is 7.1). Downgraded by one level for inconsistency of results due to high heterogeneity (I^2 70%, $p < 0.01$)

had shown conventional mindfulness intervention had both short-term effects in terms of reducing PND symptoms and long-term benefits for PPD symptom reduction [74]. Findings from another systematic review and meta-analysis indicated in subgroup analysis that digital MBIs are effective in maternal depression. However, the conclusion from that study has limitations, as evidenced by the limited number of individual studies included in the analysis assessing the digital interventions. Furthermore, the previous systematic review and meta-analysis only considered limited versions of the digitalized approach which are website and social media platforms only [43]. Similarly, another previous systematic review and meta-analysis study had concluded that digital mindfulness interventions have a significant positive effect on maternal mental health symptoms including maternal depression, despite the highly heterogeneous and small trial articles included in the analysis causing limitations to the conclusion [42].

On the other hand, another systematic review and meta-analysis indicated that MBIs can relieve maternal depression but, do not have significant advantages over other interventions and may not be useful for all pregnant women alone [75]. Possibly, it could be justified that MBIs supported with technology have a better benefit for maternal depression. Consequently, the findings of this study underscore the importance of the optimization of supporting MBIs with technology for enhanced maternal mental health outcomes.

The subgroup analyses were also employed for PND versus PPD. The intervention was effective in both phases of maternal depression and no statistically significant differences were found according to the type of depression. Similar results were found in a previous systematic review indicating that digital MBIs were effective for depressive mental health outcomes among perinatal women [42]. A systematic review and meta-analysis of the RCT studies on the effectiveness of different interventions for PPD shows that interventions other than antidepressants were not effective while it was concluded that telemedicine (digital health) was the most effective therapeutic intervention for PPD treatment [76]. Thus, this finding strengthens the cruciality of incorporating technology for the effectiveness of different interventions, including MBIs for maternal depression.

The growing body of evidence supporting digital health tends to suggest that MBI could be more effective when used with technology. A recent systematic review and meta-analysis indeed showed that mindfulness with eHealth interventions outperformed other intervention types for mental health problems [37].

The results of this study have to be analysed in light of some limitations. First, this study included all studies with which maternal depression was also a secondary outcome. The inclusion criterion was restricted to the articles published in the English language only, potentially excluding relevant studies published in other languages. The limited number of studies included in this analysis could indeed be a significant issue, especially for the subgroup analysis. For the PND and PPD, the small number of studies included in each subgroup analysis could impact the statistical power and the reliability of the results. Also, the heterogeneity across different studies can still have an impact on the overall conclusions. While some studies exhibited moderate quality, it is essential to consider their impact thoughtfully when interpreting the overall conclusions. The limited representation of data from LMICs in this review raises concerns about the generalizability of findings to these settings, despite the high prevalence of maternal depression found in these countries. In sub-Saharan African countries for example, the pooled prevalence of PPD was 22.1% ranging from 3.8 to 69.9% in the different countries [77] whereas the pooled prevalence of PND was found to be 26.3% [78]. Furthermore, the impact of maternal depression within this region is worsened by the substantial challenges observed

in the nations [78–80]. On the other hand, health technology has a crucial role in the health department to achieve Sustainable Development Goal 3 (SDG) which focuses on ensuring healthy lives and promoting well-being for all at all ages with its two main objectives, (i) achieving universal health coverage, including financial risk protection, access to quality healthcare, and access to safe, effective, quality, and affordable essential medicines and vaccines for all, and (ii) reducing premature mortality from non-communicable diseases by one third through prevention and treatment and promoting mental health and well-being by 2030 [81]. Therefore, given the higher prevalence of maternal depression in LMICs and their unique healthcare challenges, there is an urgent need for context-specific research on technology-supported MBIs in these regions. Future studies should consider the following points:

In LMICs, the implementation of technology-supported MBIs faces unique challenges related to cost and accessibility. While digital interventions may reduce the need for in-person healthcare visits, the initial investment in technology infrastructure and devices can be prohibitive in resource-limited settings [82]. Studies from high-income countries cannot be directly extrapolated to LMIC contexts due to significant differences in healthcare resources, technological infrastructure, and economic constraints [83]. Future research should focus on developing cost-effective solutions that utilize existing technology platforms, such as basic mobile phones and SMS services, which are more widely available in LMICs. Additionally, studies should evaluate the economic feasibility of implementing these interventions at scale within existing healthcare systems [84].

The cultural adaptation of MBIs for different LMIC contexts is crucial for intervention success. As highlighted in this review, current evidence comes from Western contexts with a limited understanding of how mindfulness concepts and practices translate across different cultural settings. Cultural beliefs, religious practices, and social norms significantly influence maternal mental health and healthcare-seeking behaviors in LMICs [85]. Research is needed to understand how to effectively adapt MBI content, delivery methods, and technological interfaces to be culturally appropriate and meaningful for diverse populations. This includes considering local languages, cultural beliefs about mental health, traditional healing practices, and family dynamics [25].

Integration of technology-supported MBIs into existing healthcare systems in LMICs requires careful consideration of current healthcare infrastructure and capacity. The high prevalence of maternal depression in these settings demands interventions that can be seamlessly incorporated into existing maternal health services. Research should examine how these interventions can complement, rather than burden the already stretched healthcare systems. This includes investigating the training needs of healthcare workers, the potential role of community health workers in intervention delivery, and the integration of digital platforms with existing health information systems [86].

Despite these limitations and the lack of studies from LMCIs, this systematic review exhibits several notable strengths. It represents the pioneering effort in assessing the impact of technology-supported MBI specifically for maternal depression, at least in HIC. The review completely included primary studies that adhered to a robust research design, RCTs. The study followed the PRISMA 2020 guidelines, ensuring transparency and rigor in its methodology. The absence of publication bias among the included studies further enhances the credibility of this review.

According to our analysis, technology-supported MBIs showed promise as effective therapeutic approaches for both PND and PPD. These interventions have demonstrated efficacy when administered during the prenatal period and into the postpartum phase. Given these findings, the integration of this intervention should be considered in clinical settings. The technology-supported MBI services can be conveniently delivered through various modalities for example video and audio recordings, using tablets, laptops, and smartphone applications such as app teaching modules, and online platforms including video lessons and discussions like Google Meet, online chat, and Internet-based digital therapy despite the critical importance of further research works according to the conclusion of this review to contribute significantly to advancing the effectiveness of technology-supported MBI for PND and PPD in low-income settings.

We identified that there is an important research gap in LMICs. The scarcity of research in this area underscores the importance of additional studies that investigate the effect of technology-supported MBI in these contexts. Furthermore, there is the issue of quality of evidence and considerable heterogeneity within the available studies indicating the requirement for further studies applying a robust study design such as RCT. Strengthening the evidence will enhance the confidence in the efficacy of these interventions for clinical application. This is crucially important because maternal morbidity and death remain neglected tragedies of LMICs [87].

Conclusion

This study indicated that technology-supported MBI was effective for better mental health of pregnant and postpartum women.

This study underscored the cruciality of clinics adopting technology-supported MBIs in maternal health

services. Such integration into maternal health care programs is suggested to significantly enhance maternal mental health outcomes for pregnant and postpartum women thereby encouraging the empirical evidence for the efficacy of technological applications in MBI. Furthermore, clinics should consider how technology-supported MBIs can be designed to address broader maternal health dimensions such as health-related QoL to have a more comprehensive and long-lasting impact on maternal health.

While technology-supported MBIs show promise for alleviating maternal depression, their application in LMICs remains underexplored. Investing in research within these regions is vital to ensure equitable and effective mental health interventions for all mothers, regardless of geographical and economic barriers.

Despite the high prevalence of maternal depression in LMICs, research on technology-supported MBIs in these settings remains scarce. While we had originally intended to identify research challenges and inform the design of primary studies in LMICs, including the identification of suitable technologies, the limited number of available studies precluded definitive conclusions. Therefore, we recommend prioritizing pilot and feasibility studies in LMICs to refine intervention content, identify appropriate technologies within resource constraints, and establish best practices before undertaking large-scale RCTs to evaluate intervention efficacy in these areas.

Supplementary Information

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Supplementary Material 1: Figure 1: Sensitivity analysis

Supplementary Material 2: Figure 2: Funnel plot od the studies included in the meta-analysis

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Author contributions
B.T.W and B.B carried out designing the study, data extraction, and statistical analysis. B.T.W drafted the manuscript. M.A and D.A participated in its design, article screening and selection, and supervised overall activities. All authors read and approved the final manuscript.

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Declarations

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Competing interests
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