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Neurobiological Insights and Treatment Advances in Postpartum Depression (PPD)

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Abstract

Postpartum depression (PPD) remains a major public health and psychiatric concern, persisting as an underdiagnosed and insufficiently managed condition despite advancements in global healthcare systems. Clinically, PPD typically manifests within the first four weeks to one year postpartum and is characterized by persistent low mood, anhedonia, appetite disturbances, and sleep dysregulation. The postpartum period increases vulnerability to depression. Previous reviews focused on epidemiological patterns and clinical presentations, with limited focus on underlying neurobiological mechanisms and evolving therapeutic modalities. Notable gaps include inadequate integration of hormonal fluctuations, genetic susceptibility, and neurochemical alterations implicated in PPD pathophysiology, as well as insufficient evaluation of emerging pharmacological and digital interventions. Such limitations have constrained mechanistic understanding and hindered the development of optimized, individualized treatment strategies. The present review addresses these deficiencies by providing a comprehensive and multidisciplinary synthesis of contemporary evidence. It encompasses epidemiology, hormonal insights, genetic contributions, diagnostic considerations, and the multifaceted effects of PPD. It also examines pharmacological, psychological, and non-pharmacological treatments, including cognitive behavioral therapy, interpersonal psychotherapy, social support frameworks, technology-assisted in-

terventions, internet-based and digital mental health platforms, gaming applications, and complementary approaches.

Keywords: Postpartum depression, Neurobiology, Hormonal pathways, Genetics, Digital interventions, Cognitive behavioral therapy

Introduction

Reported prevalence varies considerably, affecting up to approximately 45% of individuals in lower-income settings compared with about 10% in higher-income regions. When untreated, PPD can have serious and lasting consequences for both mother and child, influencing emotional well-being, bonding, and overall development. The condition typically emerges anytime between the first four weeks and up to one year following childbirth. The period immediately after childbirth represents a phase of increased psychological susceptibility, during which women are at increased risk for developing depressive symptoms [1]. Clinical observations suggest certain phenomenological differences: feelings of guilt and psychomotor agitation tend to be reported more frequently in PPD cases, whereas suicidal ideation and behavior appear to occur less often compared with depressive episodes arising at other stages of a woman's life. Postpartum depression is associated with several well-established risk factors. A familial predisposition to mood disorders and an individual's prior history of major depressive episodes significantly elevate vulnerability. The presence of depressive symptoms during pregnancy is also a strong predictor of postpartum onset. Interpersonal strain within the marital or partner relationship contributes to increased risk. External stressors related to infant care particularly when the newborn experiences medical complications further increase the probability of developing PPD symptoms. Manage-

ment includes pharmacologic and non-pharmacologic approaches. While antidepressant medications are an established component of therapy, many mothers express reservations regarding their safety profile, particularly during breastfeeding. Misconceptions and inconsistent information about the use of antidepressants have further discouraged from considering pharmacological intervention. non-pharmacologic strategies, especially psychotherapeutic modalities such as cognitive behavioral therapy and interpersonal therapy, tend to be more readily accepted among mothers.

Methodology

A comprehensive search of electronic databases, including PubMed, Scopus, and Web of Science, was undertaken for this narrative review. Relevant literature was identified using a combination of the following keywords: postpartum depression, postnatal depression, non-pharmacological interventions, cognitive behavioral therapy, psychotherapy, interpersonal psychotherapy, IPT, digital mental health, peer support groups, exercise, acupuncture, infant massage, newborn massage, transcranial magnetic stimulation, and light therapy.

Inclusion and exclusion criteria

The eligibility criteria encompassed studies published in peer-reviewed journals, published in English, and specifically addressing PPD in the context of non-

pharmacological interventions. Publications dated between 2020 and 2025 were considered. In addition to database searches, manual reference checks were undertaken to identify further relevant literature. The review incorporated original research articles, randomized controlled trials (RCTs), systematic reviews, and meta-analyses. Only studies examining non-pharmacological approaches for managing PPD were included in the narrative synthesis, while all others were excluded. Exclusion criteria comprised duplicate records, studies appearing in non-peer-reviewed sources, articles published in languages other than English, and papers with unavailable full texts.

Epidemiology

Despite the tendency for mental health concerns to receive lower priority in low-income countries where inconsistent access to nutrition and basic medical care dominates public health agendas and available evidence indicates that postnatal depression (PND) may be both more prevalent and more severe among women and their children in these settings. Data from resource-limited contexts, though still sparse, suggest that depressive symptoms affect more than one quarter of mothers with young infants, with reported prevalence reaching as high as 65% in certain populations. An interplay of cultural norms, interpersonal dynamics, and socioeconomic hardship appears to increase vulnerability to PND. Reported prevalence of PPD differs across global contexts, with estimates ranging from approximately 7–13% in high-income countries to over 25% in certain low- and middle-income settings [2]. Some studies suggest onset may occur during pregnancy. The most consistently identified and robust risk factor is a personal history of mood or anxiety disorders, whether occurring during the perinatal period or at other times, particularly when symptoms are present during pregnancy. Familial aggregation has also

been observed, with increased risk among women whose mothers or sisters have experienced PPD. Given that many of these determinants are shared within couples, the likelihood of concurrent depression in both parents is consequently elevated [3].

Hormonal insights

In the post-delivery period and removal of the placenta, concentrations of estrogen and progesterone decline precipitously, typically returning to pre-pregnancy levels by approximately the fifth postpartum day. Several other hormones, including beta-endorphin, human chorionic gonadotropin (hCG), and cortisol, progressively increase throughout gestation, peak near term, and then fall rapidly after childbirth [4,5]. Experimental animal data suggest estradiol enhances serotonergic neurotransmission by promoting serotonin synthesis and limiting its degradation [6-8], leading to the hypothesis that the abrupt postpartum fall in estradiol contribute to depressive symptoms. studies have not demonstrated significant differences in the magnitude of change in total estradiol or free estradiol between women with and without postpartum depression. The biologically active unbound fraction of estradiol remains insufficiently studied in this context.

Undergo postpartum fluctuations but have not been systematically evaluated in relation to postpartum depression [9, 10]. While vasopressin regulates hemodynamic and electrolyte balance; reduced urinary vasopressin has been observed postpartum, though without concurrent mood assessment [11]. Cortisol concentrations, elevated in late pregnancy due to placental corticotropin-releasing hormone (CRH) production, decline abruptly after delivery [12]. Prospective investigations controlling for lactation and psychosocial variables have not found associations between cortisol indices and postpartum mood, suggesting cortisol is unlikely to play a pri-

mary etiological role.

The marked endocrine transitions of the postpartum period have prompted hypotheses of hormonal influences in postpartum mood disorders. methodological limitations including inadequate control for breastfeeding status, diurnal variation in hormone secretion, seasonal effects, maternal sleep deprivation, and medication use have contributed to inconsistent findings. Cutting-edge work with extracellular vesicle mRNAs aims to detect brain-derived genetic signatures in blood that correlate with depression risk, potentially creating a noninvasive diagnostic blood biomarker. Beyond biomarkers, interdisciplinary innovations include AI-augmented screening techniques combining molecular data with machine learning to enhance early detection and personalized care pathways [13, 14].

Genetics

Genetic influences are increasingly recognized as important contributors to the pathophysiology of PPD. Evidence from family aggregation and twin studies indicates that PPD demonstrates familial clustering, supporting a heritable component. Investigations of candidate genes have revealed associations with polymorphisms previously linked to major depressive disorders outside the perinatal period, including the Val66Met variant of the brain-derived neurotrophic factor (BDNF) gene. Genome-wide studies have identified several susceptibility loci as well as variations in the Hemicentin-1 (HMCN1) gene, which contains multiple estrogen-responsive binding sites [15]. Collectively, these findings suggest that specific genetic variations may increase vulnerability to PPD. Recent innovations in the genetics of PPD include large meta-analyses of genome-wide association studies (GWAS) that confirm PPD is polygenic and heritable, with significant genetic correlations to major depressive disorder,

bipolar disorder, anxiety disorders, and hormonal conditions, and unique cell-type enrichments implicating inhibitory neurons in the thalamus and hypothalamus pathways, which also relate to mechanisms of brexanolone, the only FDA-approved PPD treatment (GWAS meta-analysis) [16]. A notable advancement is the identification of druggable genes through Mendelian randomization and colocalization analyses. Suggesting immune regulation as a causal pathway unravel altered B-cell activation and insulin resistance in PPD, supporting the interplay between genetic risk and immune/metabolic mechanisms [17,18].

Effects of PD

Untreated maternal depression is linked to substantial morbidity affecting the mother, infant, broader family system. Creating a painful mismatch between expectations of motherhood and the affected woman's diminished capacity to experience pleasure or fulfillment in the maternal role. They are more likely than nondepressed mothers to have histories of recent or ongoing physical, emotional, or sexual abuse [19]. The postpartum period is lower than in the general female population, suicide remains a significant contributor to maternal mortality. In several high-income settings, self-inflicted injury ranks among the leading causes of death within the first year after childbirth, and global data indicate that suicide continues to be a major cause of maternal mortality across both high- and lower-resource countries.

Maternal depression also exerts detrimental effects on infant and child outcomes. Depressive symptoms can impair a mother's capacity for sensitive and responsive caregiving, with affected women often showing reduced attunement to infant cues and increased likelihood of withdrawn, hostile, or negatively engaged parenting behaviors. Disturbances in

early mother–infant interactions are associated with poorer cognitive performance and less optimal emotional development in children, patterns observed across diverse cultural and socioeconomic contexts [20]. Persistent maternal depression further increases the risk of behavioral challenges and later psychiatric disorders in offspring, including anxiety, disruptive behavior disorders, and mood disorders. Improvement or remission of maternal depression has been associated with parallel reductions in children’s psychiatric symptoms. Maternal depression is linked to adverse feeding related outcomes, such as lower initiation and duration of breastfeeding, reduced maternal confidence in breastfeeding, and greater reported difficulties with feeding.

PD diagnosis

The diagnostic criteria for a Major Depressive Episode (MDE) outlined in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) are not modified for the postpartum period. Diagnosis requires a minimum duration of two weeks characterized by persistent depressed mood or marked loss of interest or pleasure (anhedonia), accompanied by at least four additional symptoms retardation, diminished energy, feelings of worthlessness or excessive guilt, impaired concentration, and recurrent thoughts of death or suicide. The incidence of depressive episodes increases substantially among women during the first three months following childbirth, with increased vulnerability to psychiatric disorders potentially extending for a year or longer.

Accurate diagnosis of PPD necessitates careful differentiation from other psychiatric and medical conditions. The “postpartum blues,” commonly referred to as the “baby blues,” represents a temporary emotional disturbance affecting up to three-quarters of new mothers within the first 10 days after delivery [21]. It is characterized by tearfulness, irritability, fa-

tigue, anxiety, and mood lability. These symptoms are typically mild, short-lived, and not associated with persistent low mood, anhedonia, or suicidal ideation. Women presenting with depressive symptoms, mood elevation, or psychotic features require assessment for a history of manic or hypomanic episodes to exclude previously unrecognized bipolar disorder. Such as thyroid dysfunction should be evaluated as potential contributors to psychiatric manifestations. Given the significant risks associated with untreated PPD, emphasis has increasingly been placed on timely identification and intervention during pregnancy and the postpartum period.

Researchers have also developed machine learning models that identify high-risk individuals immediately postpartum, potentially guiding care before hospital discharge. On the treatment front, the neuroactive steroid zuranolone (Zurzuvae) has emerged as a novel, rapid-acting oral medication specifically approved for PPD, providing symptom relief within weeks by targeting neurosteroid pathways rather than traditional monoamine systems [22,23]. Additional promising interventions include non-pharmacological approaches such as repetitive transcranial magnetic stimulation, mindfulness therapies, and integrative care options that broaden treatment beyond standard antidepressants.

PPD is associated with a broad range of emotional and cognitive symptoms, including marked mood instability, increased anxiety, irritability, feelings of being overwhelmed, and intrusive or persistent worries often centered on the infant’s health, feeding, or safety during routine care activities such as bathing. Suicidal ideation is notably prevalent, reported in approximately one-fifth of women experiencing PPD symptoms. In some cases, mothers may also report thoughts related to harming their infant. It is clinically essential to differentiate between genuine intent to cause harm and intrusive, obsessional thoughts. In the latter, the mother experiences dis-

troubling images or ideas of harm toward herself or her child but has no desire or intention to act on them. Immediate referral for mental health evaluation is warranted, and involvement of child protective services may need to be considered.

Structured screening tools, including the Patient Health Questionnaire-9 (PHQ-9) and the 10-item Edinburgh Postnatal Depression Scale (EPDS), can serve as useful adjuncts in identifying depressive symptoms during the perinatal period [24, 25]. A positive screening outcome on either instrument should prompt a thorough clinical evaluation to establish an accurate diagnosis.

After childbirth disorders which involve emotional or behavioral disturbances arising in response to an identifiable stressor, with symptom onset occurring within three months of the precipitating event. A key diagnostic feature is the reduction of symptoms once the stressor or its consequences diminish. The postpartum period is marked by profound physical, psychological, interpersonal, and social transitions. Women may experience pressure to regain their pre-pregnancy body shape, while also navigating decisions regarding maternity leave, return to employment, or withdrawal from the workforce—each of which may carry financial and identity-related implications.

As they frequently overlap with or coexist alongside anxiety disorders, obsessive-compulsive symptoms, and trauma-related conditions. Comprehensive clinical assessment should therefore include evaluation for excessive worry, panic symptoms, intrusive or obsessional thoughts, compulsive behaviors, and past or recent exposure to traumatic events, along with associated features such as nightmares, flashbacks, or other manifestations consistent with post-traumatic stress disorder (PTSD). Recent innovations and advancements in the understanding, screening, and treatment of PPD have focused on precision diagnostics, digital health, and novel therapeutics. A

major pharmacological breakthrough is the development of zuranolone, the first oral medication approved specifically for PPD, offering rapid relief and greater accessibility compared with older treatments like brexanolone [26, 27]. Researchers are also leveraging machine-learning-based predictive models that identify women at high risk of PPD before symptoms fully emerge, enabling earlier intervention and resource allocation. Integration of artificial intelligence (AI) into screening tools and telehealth platforms is showing promise by enhancing early detection through analysis of behavioral, linguistic, and physiological data patterns that transcend traditional questionnaires and clinician judgment.

Pharmacological Treatment

Pharmacologic management of PPD involves several considerations that distinguish from the treatment of depression at other life stages. These include physiologic and metabolic alterations occurring during the postpartum period, the potential transfer of medications to the infant through breast milk, the impact of both depressive illness and its treatment on maternal capacity to care for a newborn, and the stigma some women experience when medication use is perceived as a failure of maternal adequacy. Comparative data evaluating antidepressant therapy versus nonpharmacologic interventions in PPD remain limited; however, available evidence indicates that pharmacotherapy demonstrates effect sizes comparable to those of many psychological treatments.

Only a small number of randomized controlled trials have examined antidepressant use specifically for PPD, supplemented by several open-label investigations. Direct comparisons among antidepressant classes are rare. Secondary analyses further indicated that both agents were associated with similar improvements in maternal role functioning and sex-

ual functioning. Potential benefit of agents such as sertraline, venlafaxine, nefazodone, fluvoxamine, and bupropion; however, these investigations were limited by very small sample sizes, lack of control groups, and, in some cases, industry sponsorship [28]. A prior positive response to a specific antidepressant should weigh heavily in treatment selection for postpartum relapse. At the same time, breastfeeding considerations are central. Major health organizations advocate exclusive breastfeeding for approximately the first six months of life, stressing the need to balance maternal treatment with infant safety. Newborns are particularly susceptible to medication exposure because of immature hepatic and renal function, an incompletely developed blood–brain barrier, and ongoing neurologic maturation. While some prefer nonpharmacologic therapies, they are not universally effective or accessible. Data regarding infant exposure to antidepressants through breast milk are largely derived from case reports and small observational studies, with limited prospective evidence.

Neurobiological research highlights estrogen's role in promoting neuronal survival, enhancing neurotransmission, reducing oxidative stress, and modulating hypothalamic–pituitary axis function [29]. These findings support the hypothesis that sensitivity to hormonal fluctuations may confer vulnerability to PPD in some individuals and raise interest in hormonal approaches for prevention or treatment. Although early work suggested progesterone might help prevent recurrent PPD, subsequent randomized controlled data showed worsening depressive symptoms with the synthetic progestogen norethisterone enanthate [30]. While estrogen-based strategies remain investigational, synthetic progestogens have no established therapeutic role in PPD and may increase depressive risk, making their contraceptive use in this population potentially concerning. Studies are investigating rapid-acting treatments such as keta-

mine and esketamine for perinatal depression more broadly, as well as novel neuromodulation techniques like accelerated transcranial magnetic stimulation (TMS) to provide alternatives for women who do not respond to pharmacotherapy. Advances in biomarkers and digital phenotyping aim to improve early detection, treatment monitoring, and personalization of care for mothers during the vulnerable postpartum period.

Psychological treatment

Many women experiencing PPD are reluctant to use antidepressant medications because of worries about drug transmission to the infant through breast milk and concerns regarding possible adverse effects. Consequently, non-pharmacological approaches are often preferred, including structured psychotherapies and broader psychosocial interventions such as nondirective counseling. Interpersonal psychotherapy (IPT) is a structured, time-limited treatment for major depressive disorder that emphasizes the relationship between interpersonal functioning and mood disturbance. This approach conceptualizes depression as a medical condition that develops within a social and relational context. During IPT, the therapist and patient collaboratively identify one of four focal interpersonal domains—role transitions, interpersonal disputes, grief, or interpersonal deficits—as the primary treatment target. Adaptations of IPT for PPD specifically address issues such as the mother–infant relationship, partner dynamics, and adjustment to returning to employment. In a randomized controlled trial conducted by O'Hara and colleagues involving 120 women with PPD, participants receiving 12 weekly individual IPT sessions demonstrated significantly greater reductions in depressive symptoms, as measured by standardized scales, along with improved social functioning compared with those assigned to a

wait-list control condition [31].

Participants exhibited substantial symptom improvement that persisted at three-month follow-up. The relatively low attrition rate observed in this study was attributed, in part, to the provision of childcare [32,33]. Cognitive behavioral therapy (CBT), another extensively validated treatment for depression, is grounded in the principle that cognitive processes and behavioral patterns strongly influence emotional states. CBT aims to help individuals identify and modify maladaptive thought patterns while encouraging behavioral changes that enhance coping and reduce psychological distress. Clinical trials have evaluated CBT in PPD populations, including studies comparing varying intensities of CBT-based counseling and examining CBT combined with pharmacotherapy for women with comorbid anxiety.

Recent innovations and advancements in psychological and psychosocial interventions for PPD focus on accessibility, delivery method, and prevention. Emerging research also demonstrates the efficacy of peer-delivered group CBT delivered synchronously online by individuals with lived experience, which not only reduces depression and anxiety but also enhances social support and mother-infant relationship outcomes, with benefits maintained at follow-up. Another cutting-edge advancement is the development of technology-assisted CBT delivered by peers using apps and culturally tailored narrative approaches, showing comparable or superior outcomes to standard interventions while being scalable and cost-effective. Prevention efforts are expanding with digital Acceptance and Commitment Therapy (ACT) interventions during pregnancy aimed at improving psychological flexibility and well-being before symptoms emerge. These innovations reflect a broader shift toward digital, peer-supported, and preventive psychosocial care for postpartum depression [34, 35]. The FDA-approved oral medication zuranolone, a

synthetic neuroactive steroid that modulates GABA_A receptor, acts rapidly and can be taken at home, marking a shift from traditional antidepressants that take weeks to work. This follows the earlier breakthrough of brexanolone, the first drug specifically designed for PPD, which mimics allopregnanolone to restore inhibitory neurotransmission and quickly improve mood symptoms. Clinical trials show these treatments can deliver rapid symptom relief and sustained improvement, expanding options for individuals with severe PPD and opening avenues for further tailored neurosteroid therapies [36].

Non-pharmacological treatment

Electroconvulsive therapy (ECT) remains a therapeutic consideration for postpartum individuals experiencing severe major depressive episodes, particularly in cases characterized by treatment resistance, marked symptom severity, or psychotic features. Its clinical application in the postpartum period parallels its use in major depressive disorder more broadly, with the primary additional considerations involving anesthesia exposure and lactation. Because anesthetic agents administered during ECT are typically rapidly cleared from the body, infant exposure through breast milk can be reduced through appropriate timing of breastfeeding sessions. Bright light therapy, originally developed for seasonal affective disorder, has demonstrated antidepressant effects in nonseasonal depressive disorders as well. This modality is of particular interest in the perinatal context, as it poses no known risks to the fetus or breastfed infant. Further research is necessary to establish its efficacy specifically for postpartum depression more clearly.

Omega-3 polyunsaturated fatty acids have attracted attention as a potential intervention for perinatal mood disorders [37]. These compounds confer established health benefits during pregnancy and

the postpartum period, and some evidence suggests mood-enhancing effects in the general population. Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), abundant in fish oil, are essential for fetal central nervous system development [38], and maternal stores may become depleted during pregnancy as they are preferentially transferred to the fetus. Freeman and colleagues conducted two pilot investigations examining omega-3 supplementation for perinatal depression [39]: an open-label, flexible-dose study of combined EPA and DHA for major depressive disorder during pregnancy, and an eight-week randomized, dose-ranging trial evaluating omega-3 fatty acids in postpartum depression.

Physical activity has likewise been investigated as a strategy to mitigate PPD symptoms. The intervention group exhibited greater improvements in depression scores immediately post-treatment [40], although these differences were not sustained at three-month follow-up. In contrast they found no significant differences in depressive symptoms between intervention and control groups [41].

Social support

Interest in psychoeducation has increasingly developed as an integral component of preventive strategies for mental disorders. Psychoeducational interventions refer to structured educational approaches delivered to individuals experiencing psychological conditions or physical illnesses. Research shows the effectiveness of psychoeducation in addressing PPD, with many studies reporting encouraging outcomes. These interventions encompass a continuum of strategies, ranging from passive dissemination of information such as pamphlets, emails, and web-based resources to more active modalities, including structured group sessions involving therapeutic exercises and professional guidance. Passive approaches primarily focus on providing information

about the nature, symptoms, and management of disorders. Findings regarding passive psychoeducation have been mixed. The variations in developmental stages and age ranges may have influenced the outcomes. A hospital-based discharge education program conducted in Taiwan highlighted the importance of providing educational support during the postpartum hospital stay to sustain maternal psychological well-being [42]. The Translating Research into Practice for Postpartum Depression (TRIPPD) study, designed by Yawn et al., further indicated that the demands of new parenthood may delay therapeutic response, particularly among women experiencing high levels of anxiety and depressive symptoms [43]. Maternal self-confidence has been identified as a critical determinant of effective infant care and maternal responsiveness. Interventions incorporating home visits and educational materials have been shown to enhance maternal confidence and self-esteem. Elevated self-esteem contributes to greater maternal satisfaction in the parenting role, which in turn supports positive infant nurturing and developmental outcomes. Strengthening the maternal identity and fostering mother–infant bonding is also considered protective factors against postnatal depression. The role of social support in postpartum depression prevention is summarized in Figure 1. Young mothers and primiparous women are frequently identified as priority groups for such interventions, as limited knowledge and parenting experience may increase their vulnerability to depressive symptoms compared to multiparous mothers.

Home-visiting programs represent one of the most widely implemented early childhood intervention models [44]. Typically delivered on a weekly or monthly basis, these programs aim to mitigate the impact of social stressors on maternal mental health by providing emotional support, psychoeducation, and case management from pregnancy until the child reaches five years of age. Milani et al. emphasized the

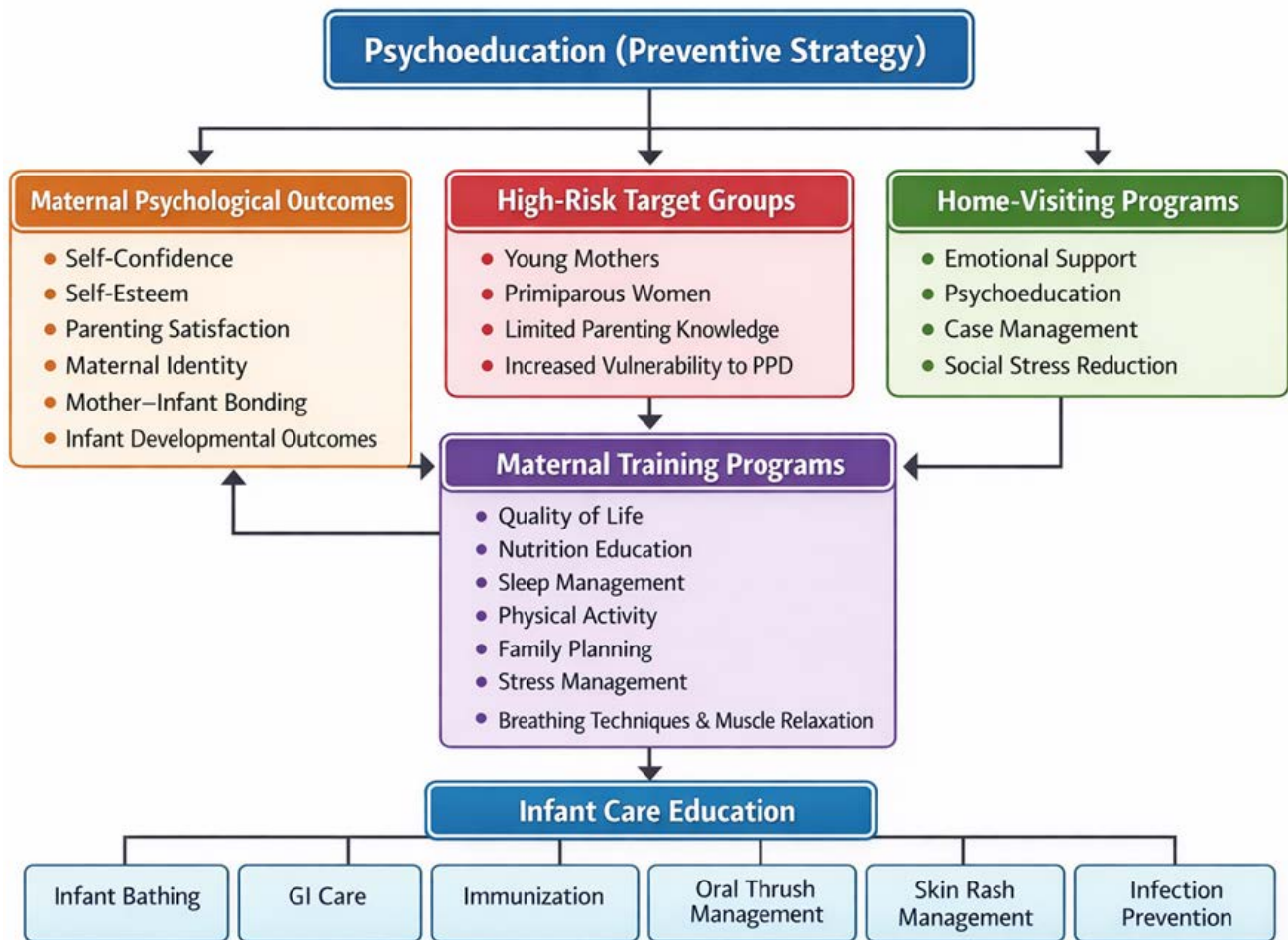


Figure 1. Social Support in PPD Prevention

positive influence of early social support through home visits on maternal adjustment to new life circumstances [45]. Although community volunteers may effectively provide parenting education and social support, their impact on maternal mental health and parenting stress appears limited, possibly due to insufficient training in mental health assessment. Christie and Bunting found that home visits by health visitors increased maternal satisfaction and reduced reliance on emergency medical services [46]. no significant improvements were observed in parenting practices or infant care outcomes. Maternal training programs often address broader aspects of quality of life, incorporating education on nutrition, sleep, physical activity, family planning, stress manage-

ment, breathing techniques, and muscle relaxation. Infant care education covers essential topics like bathing, managing gastrointestinal discomfort, immunization, treating oral thrush and skin rashes, weight monitoring, and preventing infectious diseases. A supportive home environment is linked to lower depressive symptoms and improved quality of life, which enhances information delivery and psychosocial support.

Gaming App

A pilot investigation examined an innovative mobile gaming application, The Guardians, developed as a behavioral activation (BA) intervention for preg-

nant women experiencing elevated depressive symptoms [47]. In 2024, the U.S. FDA approved Rejoyn, a prescription smartphone app delivering cognitive behavioral therapy (CBT) exercises alongside timed engagement prompts, with randomized controlled trials showing greater reduction in depressive symptoms than a placebo app, highlighting a regulatory milestone for digital therapeutics in depression treatment [48]. An overview of current app-based interventions for postpartum depression is provided in Table 1.

Non-pharmacological and Digital Interventions

Cognitive Behavioral Therapy (CBT) is a structured, time-limited psychotherapeutic intervention

designed to assist individuals in identifying and modifying maladaptive behaviors and distorted cognitive patterns that contribute to depressive symptomatology. The approach integrates cognitive restructuring, psychoeducation, and behavioral modification techniques to foster more adaptive thinking styles and to develop effective coping mechanisms. In low and middle income countries, telephonic delivery of CBT has emerged as a practical strategy to expand access to mental health services, particularly in contexts where awareness of PPD and availability of care are limited. A randomized controlled trial conducted by Fuhr et al. in India demonstrated the feasibility of task-shifting, wherein trained laywomen from local communities delivered CBT-based interventions [54]. The study reported a

Table 1. App-Based Interventions for Postpartum Depression

Gaming App	Type of Digital Approach	Mechanism / Key Features	Study Design & Outcome	Reference
Motherly app	CBT-based smartphone mental health app (behavioral activation modules, interactive tasks)	Cognitive-behavioral therapy exercises, mood tracking, behavioral activation, sleep and stress management	Randomized controlled trial (2024): No significant reduction in PPD vs control, but improvement in anxiety, sleep, parental stress; higher engagement linked to better outcomes	[49]
InBloom app	Asynchronous digital behavioral intervention (gamified engagement elements)	Digital psychoeducation, behavioral skills training, mood regulation modules; based on ROSE program	Ongoing RCT (2025 protocol) evaluating prevention of postpartum depression vs in-person intervention	[50]
Nurse-led lifestyle mHealth app	Behavioral health app (exercise, diet, education modules)	Lifestyle coaching, exercise supervision, sleep and fatigue monitoring, health education	RCT (2024): Significant improvement in depression scores, sleep, and fatigue in postpartum women	[51]
MBapp (Mothers & Babies program adaptation)	CBT-based digital prevention app with interactive learning	Psychoeducation, mood management, coping skills training, user-engagement feedback	Qualitative feasibility study (2024); pilot RCT planned to test prevention of PPD	[52]
Powerly app	Personalized CBT-based digital therapeutic with behavioral tasks	Emotion regulation training, mental health tracking, bonding enhancement, personalized modules	Randomized clinical trial underway (2024–2026) to assess reduction of postpartum depression and anxiety	[53]

moderate reduction in depressive symptoms, supporting this model as a cost-effective and scalable alternative to specialist-led care.

The "Happiness, Understanding, Giving, and Sharing" (HUGS) program is an intervention aimed at strengthening mother–infant bonding among mothers experiencing PPD, addressing evidence that maternal depression adversely affects early relational development [55]. This program extends beyond symptom management by equipping mothers with practical relational and caregiving skills. The first session focuses on interactive play, the significance of physical closeness, identification of bonding difficulties, and problem-solving strategies. The second session emphasizes recognizing and interpreting infant cues while promoting positive engagement through structured activities. In the third session, mothers are guided in responding sensitively to their infants' signals and in challenging negative cognitions that may interfere with nurturing interactions. Telehealth and online CBT delivery have expanded with peer-delivered group CBT, showing significant reductions in depressive and anxiety symptoms and improvements in social support and infant outcomes, and remain beneficial up to months post-intervention, highlighting peer support as a scalable model for PPD care [56]. In brief 1-day peer-delivered CBT workshops delivered online also significantly reduce PPD symptoms and associated anxiety, parenting stress, and improve mother-infant relationships while being cost-effective [57]. AI and digital tools incorporating conversational agents and digital screening show potential for expanding access to psychotherapeutic support and early intervention [58–60].

Interpersonal Psychotherapy (IPT) primarily concentrates on the enhancement of interpersonal functioning as a pathway to improving psychological well-being. Its efficacy has been empirically examined across a range of mental health conditions, in-

cluding depressive disorders, anxiety disorders, and post-traumatic stress disorder. Owing to its adaptable structure, IPT can be implemented in diverse contexts such as inpatient facilities, community settings, and individual outpatient care. The therapeutic model is grounded in the premise that an individual's emotional state is closely linked to the quality of their relationships and to significant life events. IPT conceptualizes distress within four principal interpersonal domains: bereavement, role transitions, social isolation, and interpersonal disputes. Treatment typically unfolds in three structured phases. The initial stage involves establishing a therapeutic alliance, conducting a comprehensive psychosocial assessment, and developing a clinical formulation. During this phase, the therapist identifies salient interpersonal problem areas and collaborates with the client to create a focused treatment plan. Empirical findings, such as those reported by Xang *et al.*, indicate that IPT delivered for periods exceeding twelve weeks to mothers experiencing depression was associated with reductions in Edinburgh Postnatal Depression Scale (EPDS) scores and improved family-related satisfaction [61].

Internet-Based Intervention

A randomized controlled trial (RCT) in the United Kingdom, known as Netmums, implemented a 12-session web-based intervention targeting participants who had elevated scores on the Edinburgh Postnatal Depression Scale (EPDS) [62]. The structured program addressed themes including maternal depression, the transition to motherhood, and infant care. The study incorporated opportunities for postpartum mothers to interact with fellow participants, thereby facilitating peer support an important psychosocial component.

Similarly, an interventional study conducted in Germany by Schmidt JH *et al.*, PandaMom, utilized a cog-

nitive behavioral therapy (CBT) framework delivered through a self-guided digital platform [63]. Eligible individuals gained program access following online registration. The intervention comprised psycho-educational content, self-assessment tools, structured workbooks, and exercise-based video materials. Such technology-driven interventions exemplify emerging directions in PPD research, highlighting innovative, scalable strategies for mental health support.

Bhardwaj A. et al conducted a study in Nepal involving mothers who scored above nine on the PHQ-9, indicating clinically relevant depressive symptoms. The study integrated digital health tools, including Android smartphones and smartwatches, to monitor physical activity patterns such as walking and vehicular movement [64]. Mothers experiencing depression were encouraged to engage in structured, mood-enhancing activities and to establish specific, achievable behavioral goals, for instance, temporarily entrusting the infant to a family member in order to visit a local market. Trained counselors provided follow-up support to ensure goal attainment. To assess mother–infant proximity, a Bluetooth beacon was attached to the infant’s clothing, enabling measurement of the physical distance between mother and child through signals captured by the mobile device. This metric was relevant given prior evidence suggesting that depressed mothers often experience limited social support and may spend disproportionate amounts of time exclusively with their children. Data collected from these monitoring systems were visualized through the mobile application Stand Strong, which served as a central platform for tracking behavioral indicators. Counselors reviewed these data during therapeutic sessions to inform personalized guidance.

Alternative medicine for PD

A randomized controlled trial conducted by Lewis and colleagues investigated postpartum women with

a prior history of depression. Participants were assigned to one of three groups: a telephone-delivered exercise intervention, a telephone-based wellness and support program, or usual care, each implemented over six months [65]. The intervention was specifically designed to address common barriers to in-person participation, such as childcare responsibilities, travel expenses, and time limitations, while still providing individualized counseling. Findings indicated that women in the exercise intervention group experienced a greater reduction in depressive symptoms compared with those in the wellness/support group. Complementary evidence from a meta-analysis suggests that moderate-intensity aerobic exercise performed for 35–45 minutes yields more pronounced improvements in depression scores than either low- or high-intensity regimens [66,67]. CAT encompasses diverse modalities, including music, visual arts, dance, sculpture, drama, film, and poetry. These nonverbal forms of expression allow individuals to process emotions therapeutically without reliance on pharmacological treatment, which often increases acceptability among patients and families and may enhance adherence to care. Despite growing recognition of its psychological benefits, the integration of CAT into clinical practice particularly in the context of PPD) remains in its developmental stages. Healthcare institutions worldwide are increasingly acknowledging maternal mental health and exploring CAT as a supportive intervention.

The intervention consisted of 16 instructor-led sessions over eight weeks [68]. Participants who engaged in yoga demonstrated significant improvements in depression scores by the study’s conclusion. Acupuncture, a modality rooted in traditional Chinese medicine, has also been explored as an alternative treatment for depressive disorders. Although its application in PPD is debated, a systematic review and meta-analysis by Li et al. reported signif-

icant reductions in HDRS scores among postpartum women receiving acupuncture [69]. Infant massage programs led by trained facilitators have been associated with improved maternal infant bonding and reductions in depressive symptoms. Such programs provide opportunities for peer interaction, fostering social support among new mothers. Participants frequently report enhanced self-confidence and a stronger sense of attachment to their infants, attributed to increased quality of shared time, physical touch, and eye contact during massage activities.

Emerging noninvasive neuromodulation techniques, such as transcranial magnetic stimulation (TMS), have also been investigated for PPD, though evidence regarding efficacy and safety remains limited. In a study by Kim and colleagues, pregnant women in the latter half of gestation underwent 20 sessions of low-frequency (1 Hz) TMS administered at 100% of motor threshold to the right dorsolateral prefrontal cortex, totaling 6000 pulses [70]. Seven out of ten participants exhibited substantial reductions in depressive symptoms without reported fetal harm. Light therapy, which involves exposure to a calibrated light source, has likewise been studied for depressive disorders. By stimulating intrinsically photosensitive retinal ganglion cells, it may improve mood and regulate sleep patterns. An early open-label trial involving pregnant women with major depressive disorder demonstrated significant symptom improvement following light therapy.

Acupuncture, a traditional Chinese medical practice involving needle insertion and manipulation at specific body points, has been explored as a treatment for depressive disorders with mixed findings. Its use during pregnancy has expanded, particularly as an adjunctive intervention for conditions such as nausea, pain, breech presentation, and labor induction. In a comparative study, Manber et al. evaluated depression-specific acupuncture against both non-specific acupuncture and massage controls in preg-

nant individuals with depression [71].

Conclusion

PPD represents a substantial public health concern, exerting profound and enduring effects on maternal psychological well-being as well as on mother–infant attachment and early relational development. Although pharmacological approaches, particularly antidepressant medications, continue to constitute the conventional standard of care, increasing attention is being directed toward non-pharmacological interventions. These approaches are especially relevant for breastfeeding mothers, for whom concerns about medication-related adverse effects often influence treatment decisions. Evidence indicates that such therapeutic modalities can effectively reduce depressive symptomatology while simultaneously promoting healthier maternal behaviors and strengthening mother–child bonding. Despite their promise, significant challenges persist, including limited accessibility, insufficient personalization of treatment strategies, and a shortage of large-scale, methodologically rigorous research. Future research must aim at optimizing interventions, implementing well-structured clinical trials, and systematically sharing results. In supporting these efforts through sustained funding, ensuring equitable access, encouraging family-wide awareness and involvement, promoting cultural relevance, and integrating these services into routine maternal healthcare systems.

Conflict of interest

Conflict of interest declared none.

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