

Research Progress on the Mechanism of Emotional Regulation in the Late Pregnancy from the Perspective of Social-Psychological-Biological Interaction

Danfeng Fan

Women's Hospital School of Medicine Zhejiang University, Hangzhou, Zhejiang, China

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Abstract: The third trimester is a critical period for maternal transition from pregnancy to postpartum. Its emotional state not only affects maternal physical and mental health but also profoundly shapes early neurodevelopment and emotional regulation in offspring through the "fetal programming" mechanism. This review systematically examines the physiological, psychological, and social dimensions of emotional regulation during the third trimester from a socio-psychobiological interaction perspective, aiming to provide insights for improving maternal and infant health outcomes.

1. Introduction

The third trimester, as a critical transitional phase from pregnancy to postpartum, not only directly impacts maternal physical and mental health but also shapes early developmental trajectories of offspring through multidimensional pathways. During this period, women undergo profound physiological, psychological, and social role transitions: fluctuations in hormone levels, anxiety about childbirth, and adaptation pressures to maternal roles collectively present complex challenges for emotional regulation. Studies indicate that variations in emotional regulation capacity during the third trimester are strongly associated with adverse pregnancy outcomes, including increased risks of preterm birth, low birth weight in neonates, and persistent postpartum depression symptoms [1,2]. More importantly, the quality of maternal emotional regulation exerts profound effects on offspring through the "fetal programming" mechanism. A prospective study demonstrated that maternal emotional regulation difficulties may influence fetal neurodevelopment via the placental-fetal axis [3]. Current clinical practice still inadequately addresses emotional regulation during the third trimester. Traditional obstetric care often focuses on physiological indicators, while assessments of emotional states are limited to postpartum depression screening, neglecting this critical intervention window. In fact, enhancing emotional regulation capacity during the third trimester can not only reduce the incidence of postpartum psychological disorders but also promote early emotional regulation development in infants by improving maternal-infant interaction quality. Growing evidence suggests that emotional regulation is the result of dynamic interactions among social, psychological, and biological factors, and any single-dimensional explanation fails to fully capture its complexity. This review aims to systematically elucidate the

mechanisms of emotional regulation during the third trimester within a socio-psychobiological interaction framework, providing insights for improving maternal and infant health outcomes.

2. Psychological Mechanisms of Emotional Regulation in Late Pregnancy

2.1 Cognitive Assessment and Emotional Regulation

Cognitive evaluation, as a core psychological process in emotional regulation, exhibits unique adaptive characteristics during the third trimester of pregnancy. Throughout gestation, the interpretation of physiological changes, fetal health, and role transitions by pregnant women directly influences the nature and intensity of their emotional experiences. For instance, excessive focus on fetal movement frequency may be misinterpreted as fetal abnormalities, triggering anxiety; conversely, reinterpreting it as a sign of fetal vitality can alleviate such concerns [9]. These differences in cognitive reinterpretation are not only related to individual emotional regulation abilities but also closely intertwined with the unique psychosocial context of the third trimester.

From the perspective of social cognitive theory, the core of cognitive evaluation in late pregnancy lies in the "risk-benefit" trade-off. The alignment between a pregnant woman's subjective assessment of pregnancy risks and actual medical risks directly predicts the effectiveness of emotional regulation. Studies indicate that excessive risk amplification is significantly positively correlated with pregnancy-related anxiety symptoms, whereas rational evaluation based on medical knowledge can mitigate negative emotions [5]. Additionally, cognitive evaluation in late pregnancy involves a redefinition of self-efficacy—the pregnant woman's assessment of her "competence in the maternal role"—which indirectly influences mental health by affecting the selection of emotional regulation strategies [8].

The dynamic nature of cognitive evaluation becomes particularly pronounced in the third trimester. As gestational weeks progress, pregnant women's emotional attachment to the fetus gradually strengthens, which reshapes their interpretation of the significance of pregnancy-related events. For instance, negative evaluations of weight gain during early pregnancy may shift to positive cognition in the third trimester due to fetal developmental needs. This dynamic adjustment relies on the cognitive control function of the prefrontal cortex, while the dramatic fluctuations in estrogen levels during the third trimester may alter the activation patterns of this brain region, thereby modifying the flexibility of cognitive evaluation. Notably, cognitive evaluation is not an isolated process; it forms a complex interactive network with social support and biological factors, collectively influencing the effectiveness of emotional regulation [5,7].

2.2 Personality Traits and Emotional Regulation

As a stable predictor of emotional regulation, personality traits exhibit complex interactions with biological and social factors during the third trimester. Neuroticism, the most central personality dimension, directly influences regulatory capacity by modulating the sensitivity of emotional processing. Studies indicate that highly neurotic pregnant women are more prone to emotional regulation difficulties in the third trimester, and this association is not fully buffered by social support. At the neural mechanism level, individuals with high neuroticism exhibit larger amygdala volumes and heightened responsiveness to negative stimuli, while elevated estrogen levels during the third trimester may further amplify this sensitivity, leading to excessive depletion of emotional regulation resources. Additionally, neuroticism indirectly weakens emotional regulation efficacy by influencing cognitive evaluation bias [9].

The relationship between extraversion and emotional regulation demonstrates situational specificity during late pregnancy. Extraverted pregnant women tend to employ social support-

seeking strategies, which effectively alleviate negative emotions in high-stress situations. However, extraversion may also impose additional stress by increasing social exposure, particularly when social interactions involve negative comparisons. Notably, the positive effects of extraversion on emotional regulation depend on the quality of social networks—extraverted pregnant women may experience regulatory failure due to unmet social needs in environments lacking effective support [10].

Responsibility directly impacts late pregnancy mental health by influencing the effectiveness of emotional regulation strategies. High responsibility levels enable pregnant women to consistently employ adaptive strategies, maintaining regulatory effects even under stress [4]. A Dutch study found that responsibility scores showed a significant positive correlation with cognitive reappraisal frequency, which mediates the negative association between responsibility and postpartum depression. However, excessive responsibility may lead to "self-blame" —pregnant women's unrealistic expectations for emotional regulation performance, which paradoxically triggers anxiety. Additionally, responsibility interacts with biological factors: high responsibility levels result in more stable placental cortisol regulation, potentially strengthening the physiological basis of emotional regulation.

Openness is closely associated with emotional regulation flexibility. Pregnant women with high openness are more likely to adopt new regulation strategies and adapt their strategy selection according to situational changes. This flexibility is particularly crucial in the third trimester, as pregnant women need to cope with continuously changing physiological and psychological challenges. Studies have shown that pregnant women with higher openness scores exhibit richer diversity in their emotional regulation strategies, which is associated with lower levels of pregnancy anxiety. However, openness may also pose risks—excessive exploration of pregnancy-related information may lead to information overload, which can interfere with emotional regulation. Notably, personality traits are not static predictors; psychosocial transitions in the third trimester may reshape the association patterns between personality and emotional regulation [12].

2.3 Fetal Attachment and Emotional Regulation

Fetal attachment, as a unique psychological bond in late pregnancy, profoundly influences emotional regulation by reshaping neural circuits for emotional processing and selecting regulatory strategies. The core dimensions of fetal attachment include emotional connection to the fetus, imagined interactions, and role expectations, which exhibit multi-path mechanisms in their relationship with emotional regulation. Studies indicate that the intensity of fetal attachment in late pregnancy is significantly positively correlated with the frequency of cognitive reappraisal—positive emotional connections between pregnant women and their fetuses enhance their motivation to reconstruct pregnancy-related stress, thereby improving regulatory efficacy. Imagining the fetus's "response" to one's emotions helps pregnant women transform negative emotions into protective motivations, subsequently adjusting cognitive evaluations [14].

The neural mechanisms underlying fetal attachment's influence on emotional regulation involve interactions between the oxytocin system and the limbic system. During late pregnancy, the formation of fetal attachment is accompanied by increased oxytocin secretion. This hormone reduces the reactivity to negative emotions and enhances cognitive control by acting on the amygdala and prefrontal cortex. An fMRI study found that pregnant women with high fetal attachment exhibited significantly enhanced prefrontal cortex modulation of the amygdala when viewing fetal ultrasound images, a neural pattern associated with better emotional regulation performance. Additionally, fetal attachment may indirectly affect the physiological basis of emotional regulation by regulating placental hormone secretion.

The dynamic relationship between fetal attachment and emotional regulation exhibits a "bidirectional influence" pattern during the third trimester. On one hand, effective emotional regulation enhances fetal attachment formation—pregnant women employing cognitive reappraisal strategies are more likely to interpret fetal physiological signals as positive interactions, thereby strengthening emotional bonding. Conversely, the intensity of fetal attachment also influences the efficacy of emotional regulation strategies: pregnant women with high attachment levels demonstrate significantly lower physiological arousal of negative emotions when using expression suppression compared to those with low attachment, which may be attributed to the buffering effect of oxytocin [4]. This bidirectional interaction becomes more pronounced in prenatal stress situations: pregnant women with childhood trauma experience aggravated emotional regulation difficulties due to impaired fetal attachment, while targeted attachment interventions can improve regulatory capacity [15].

The influence of individual differences in fetal attachment on emotional regulation operates through a mediating pathway. Research demonstrates that fetal attachment indirectly affects emotional regulation by modulating maternal self-efficacy—pregnant women with high attachment levels exhibit stronger confidence in their maternal role, which enhances their adaptive resilience to pregnancy-related stress [6]. Furthermore, fetal attachment interacts with social support: in environments with low partner support, high attachment may partially buffer difficulties in emotional regulation, while in high-support environments, the synergistic effect becomes more pronounced [16]. Notably, fetal attachment is not always adaptive—excessive attachment may lead to overconsumption of emotional regulation resources, thereby increasing anxiety risks. This complexity suggests that the relationship between fetal attachment and emotional regulation requires comprehensive consideration of biological and social factors [11].

3. Social Factors of Emotional Regulation in the Third Trimester of Pregnancy

3.1 The Role of Family Support Systems

3.1.1 Marital Attachment and Emotional Interaction

The family support system, as a core social environmental factor for emotional regulation in late-pregnancy women, directly influences maternal emotional regulation capacity through the quality of marital attachment and emotional interaction patterns. Marital attachment refers to the emotional bond formed between pregnant women and their partners, which not only provides emotional support but also shapes maternal emotional regulation strategies through daily emotional interactions. Studies indicate that the "attachment anxiety" dimension in marital attachment is a key factor affecting emotional health in late-pregnancy women. Pregnant women with higher levels of attachment anxiety are more prone to depressive and anxious symptoms as well as fear of childbirth, while emotional support from partners can significantly mitigate these risks. In a study of 325 first-time late-pregnancy primiparas, partner's emotional support was negatively correlated with maternal anxiety levels, and this moderating effect was independent of other sociodemographic factors such as education level. Additionally, marital emotional interaction patterns indirectly influence maternal mental health by affecting emotional regulation strategies. When partners employ positive emotional regulation strategies, the association between maternal emotional regulation difficulties and anxiety symptoms is significantly weakened; conversely, if partners lack such interpersonal emotional regulation strategies, it exacerbates maternal emotional dysregulation [10]. This interaction mechanism has also been validated in cross-cultural studies. For instance, in Taiwan, China, the increase in postpartum anxiety levels among ART-conceived pregnant women was directly related to insufficient partner support during pregnancy, while positive marital emotional

interactions could reduce psychological vulnerability in ART-pregnant women.

The impact of spousal attachment on emotional regulation in late pregnancy is also reflected at the neurophysiological level. A neuroimaging study of women in late pregnancy revealed that the perceived level of spousal support correlates with the brain's processing patterns of emotional stimuli: when pregnant women reported higher levels of spousal support, the activation of the prefrontal cortex, which is responsible for emotional regulation, was significantly reduced in response to negative stimuli, and the amygdala's reactivity was correspondingly diminished. This neural-level regulation may constitute the biological basis for how spousal support improves emotional regulation [6]. Additionally, spousal support indirectly modulates emotions by influencing the perception of stress in pregnant women. Pregnant women who perceived higher levels of spousal support in late pregnancy exhibited significantly lower levels of pregnancy-related stress, thereby reducing the occurrence of emotional regulation difficulties [9]. This stress-buffering effect is particularly pronounced in high-risk pregnant populations, such as those hospitalized due to cervical shortening, where the emotional support provided by their partners was positively correlated with optimism levels, which in turn further reduced the burden of emotional regulation.

3.1.2 Cross-cultural Family Emotional Communication Patterns

The differences in family emotional communication patterns across cultural backgrounds significantly influence the emotional regulation process of women in the third trimester. Variations in cultural norms for emotional expression, expectations of family roles, and ways of obtaining social support shape unique emotional regulation strategies among pregnant women. In China, family emotional communication emphasizes "subtlety" and "collectivism," with pregnant women tending to regulate emotions through indirect support within the family, while direct emotional expression is relatively rare [14]. A study on advanced maternal age in China revealed that family-provided economic assistance, care services, emotional understanding, and encouragement significantly alleviate depressive symptoms, with this support being more effective in advanced maternal age than in younger pregnant women [12]. This may be related to the intergenerational transmission of family roles in Chinese culture, where advanced maternal age relies more on family networks to cope with pregnancy-related stress.

In Western cultures, family emotional communication emphasizes "individualism" and "directness." Pregnant women tend to proactively seek emotional support from partners or family members and regulate their emotions through open emotional expression. A cohort study in Australia found that the frequency of emotional interactions between pregnant women and their partners was significantly correlated with postpartum emotional availability. High-frequency positive emotional interactions can enhance the emotional regulation capacity of pregnant women, thereby improving the mother-infant relationship. Additionally, the emphasis on "joint parenting" in Western culture further positions partners as more proactive participants in emotional communication.

The differences in cross-cultural family emotional communication patterns are also reflected in preferences for emotional regulation strategies. Japanese pregnant women tend to use "expression suppression" strategies to regulate emotions, a preference closely related to the Japanese cultural value of "harmony as the highest principle," which emphasizes maintaining family harmony by suppressing negative emotional expressions. In contrast, families in Middle Eastern cultures such as Israel place greater emphasis on "emotional sharing," where pregnant women seek support by sharing their emotional experiences with family members. This strategy is particularly crucial for pregnant women in conflict zones, effectively alleviating the emotional stress caused by war [7]. Additionally, intergenerational differences within cross-cultural families can influence the effectiveness of emotional communication. For example, in immigrant families, younger pregnant

women may prefer modern emotional regulation strategies such as mindfulness and cognitive reappraisal, while older generations rely more on traditional family support methods. These intergenerational differences may lead to emotional communication barriers, thereby affecting the emotional regulation of pregnant women [13].

3.2 Influence of Socio-Cultural Background

The socio-cultural context indirectly influences pregnant women's emotional regulation by shaping their values, expectations, and social roles. Significant cultural differences exist in the definition of the "mother role," perceptions of pregnancy-related emotions, and attitudes toward mental health, which collectively form the cultural context for emotional regulation during pregnancy. In Latin America, the "family-first" value system makes pregnant women more reliant on family networks for emotional support, while societal expectations of "strong mothers" may lead to the suppression of negative emotions [11]. Research indicates that childhood exposure to threatening events indirectly affects pregnancy-related mental health through emotional dysregulation, whereas family support can mitigate this risk, reflecting the central role of family in emotional regulation within Latin American culture [11].

The socio-cultural background also influences pregnant women's cognition of emotional issues and their seeking behavior for help. In some traditional cultures, emotional problems during pregnancy are regarded as "normal physiological reactions," and pregnant women may be reluctant to seek professional help, instead relying on traditional methods such as family or community religious rituals to regulate their emotions [13]. In rural China, pregnant women's emotional regulation relies more on the experiential guidance of family members, with lower acceptance of psychological counseling, which may lead to delayed treatment of emotional issues due to such cultural perceptions [12]. In contrast, in the West, there is a higher emphasis on mental health, and pregnant women are more willing to actively seek professional support by participating in prenatal psychological intervention courses or undergoing cognitive behavioral therapy [15].

Gender role expectations in culture also significantly influence emotional regulation during late pregnancy. In many cultures, women are expected to maintain a "positive and optimistic" emotional state throughout pregnancy. This expectation may lead pregnant women to adopt "surface acting" strategies to conceal negative emotions, thereby increasing the burden of emotional regulation. A study in Israel found that pregnant women hospitalized due to cervical shortening often employed deep emotional regulation strategies such as suppressing fear to meet societal expectations of being "good mothers." Although these strategies can temporarily maintain social approval, they may exacerbate emotional fatigue in the long term. Additionally, gender role expectations affect partners' support behaviors. In cultures with strong traditional gender role concepts, partners may prioritize practical support such as financial assistance while neglecting emotional support, which is detrimental to pregnant women's emotional regulation.

The influence of socio-cultural background is also reflected in differences in the perception of stressors during pregnancy. In developed countries, pregnant women's stressors are more often related to career development and childcare costs, whereas in developing countries, they may face more pressure related to insufficient medical resources and food safety [10]. This difference in stressors leads to divergent emotional regulation strategies among pregnant women across cultures: those in developed countries tend to employ individual emotional regulation strategies such as mindfulness, while those in developing countries rely more on social support systems [11]. Additionally, religious beliefs within a culture can also influence emotional regulation. For instance, pregnant women with strong religious beliefs may regulate their emotions through practices such as prayer and meditation, a strategy that has been shown in some studies to effectively reduce

pregnancy-related anxiety.

3.3 Medical Resources and Professional Support

The accessibility and quality of medical resources are important social factors affecting emotional regulation in late pregnancy. Medical resources not only include physical facilities such as hospitals, but also professional mental health services, prenatal education, and support from healthcare professionals. Studies have shown that in areas with adequate medical resources, pregnant women have more opportunities to receive emotional support and stronger emotional regulation abilities, while in areas with scarce medical resources, the incidence of emotional problems among pregnant women significantly increases [13]. In a study conducted in Shenzhen, China, the incidence of depressive symptoms among older pregnant women was negatively correlated with the accessibility of medical resources. In communities with sufficient medical resources, the level of depression among pregnant women was significantly lower than in resource-scarce communities [12].

The role of professional support in emotional regulation during late pregnancy is primarily manifested in the following aspects: First, the emotional support provided by healthcare professionals can directly improve the emotional state of pregnant women. For example, during prenatal examinations, the active listening and emotional responsiveness of physicians or nurses can significantly reduce the anxiety levels of pregnant women. Second, professional prenatal education courses, such as teaching mindfulness and breathing exercises, can enhance the emotional regulation abilities of pregnant women. A randomized controlled trial involving late-pregnancy women demonstrated that an 8-week mindfulness-based cognitive therapy (MBCT) significantly reduced depressive and anxiety symptoms in pregnant women and improved their emotional regulation abilities, with these effects persisting for one month postpartum. Additionally, professional mental health services are particularly crucial for pregnant women with emotional disorders. For instance, cognitive behavioral therapy (CBT) interventions targeting pregnancy-related anxiety can significantly reduce anxiety levels and decrease the incidence of postpartum depression.

The quality of medical resources also indirectly influences emotional regulation by affecting the healthcare experience of pregnant women. In studies involving pregnant women who terminated pregnancies due to fetal abnormalities, humanistic care during medical procedures significantly reduced post-traumatic stress symptoms. Additionally, interdisciplinary collaboration within medical resources can enhance the effectiveness of emotional support. For instance, joint interventions by obstetricians and psychologists enable a more comprehensive assessment of the emotional state of pregnant women and provide personalized adjustment strategies [1].

Among special populations, the role of medical resources is more critical. Studies have shown that ART (Assisted Reproductive Technology) pregnant women exhibit significantly higher levels of depression and anxiety compared to those conceived naturally, and targeted medical support can effectively reduce this risk. Additionally, adolescent pregnant women require specialized medical resource support, such as emotion regulation courses tailored to their developmental stages and family support programs, to enhance their emotional regulation capabilities.

3.4 The Dual Impact of Social Media on Emotional Regulation

As an important information dissemination and social platform in modern society, social media exerts a dual impact on the emotional regulation of women in the third trimester of pregnancy: on one hand, it provides emotional support, information access, and social connections, promoting positive emotional regulation; on the other hand, it may also lead to information overload, social

comparison, and the spread of negative emotions, exacerbating emotional dysregulation.

The positive impacts are primarily manifested in the following aspects: Firstly, social media provides pregnant women with new channels for emotional support. Through forums, WeChat groups, and similar platforms, pregnant women can share their emotional experiences with others who have similar experiences, gaining emotional resonance and practical advice. This interpersonal support can effectively alleviate loneliness and anxiety during pregnancy. Secondly, social media serves as a crucial source of prenatal information. Pregnant women can access professional prenatal knowledge and emotional regulation techniques through these platforms, thereby enhancing their self-efficacy. Additionally, social media facilitates connections between pregnant women and their families and friends. Even when physically distant, emotional support can be obtained through video calls, sharing on social media, and other means.

However, the detrimental effects of social media on emotional regulation cannot be overlooked. Firstly, information overload and misinformation may elevate anxiety levels among pregnant women. Secondly, the 'ideal pregnancy' image promoted on social media could trigger social comparison, leading to self-denial and emotional distress. Additionally, social media may serve as a conduit for negative emotions, such as when pregnant women excessively display their negative emotions on these platforms, potentially inducing group anxiety.

The dual impact of social media manifests differently across demographic groups. Young pregnant women and primiparas exhibit greater dependence on social media for information and support, with their emotional regulation being more influenced by platform characteristics. In contrast, multiparous women tend to use social media more rationally, filtering out negative information. Furthermore, cultural context significantly affects social media utilization patterns. For instance, in collectivist cultures, pregnant women are more likely to seek group support through social media, whereas in individualist cultures, they may prioritize personalized information.

4. Biological Basis of Emotional Regulation in Late Pregnancy

4.1 Regulation of the Neuroendocrine System

The neuroendocrine system serves as the core biological foundation for emotional regulation during late pregnancy, with the functional state of the hypothalamic-pituitary-adrenal (HPA) axis being particularly critical. Activation of the HPA axis begins with the hypothalamus secreting corticotropin-releasing hormone (CRH), which is subsequently processed by the pituitary gland to stimulate the release of adrenocorticotrophic hormone (ACTH), ultimately leading to the secretion of glucocorticoids (e.g., cortisol) by the adrenal cortex. In late pregnancy, maternal HPA axis activity is significantly elevated, which reflects both the physiological demands of pregnancy—cortisol plays a role in promoting fetal lung maturation and other processes—and the heightened maternal sensitivity to emotional stress. Studies indicate that maternal anxiety or depressive symptoms during late pregnancy can lead to persistent HPA axis activation, resulting in abnormally elevated cortisol levels and thereby disrupting the neuroendocrine basis of emotional regulation.

The placenta, as a critical endocrine organ between the mother and fetus, serves as a "gatekeeper" in the regulation of the HPA axis. The placenta expresses 11 β -hydroxysteroid dehydrogenase 2 (HSD11B2), which converts active cortisol into inactive corticosterone, thereby limiting the transfer of maternal glucocorticoids to the fetus. However, maternal emotional stress during late pregnancy significantly affects placental HSD11B2 expression. For instance, in the placentas of pregnant women exposed to Hurricane Sandy, HSD11B2 expression levels were markedly downregulated, leading to increased active glucocorticoids entering the fetal circulation, which subsequently impaired the HPA axis function and emotional regulation capacity of the offspring. Additionally, the placenta itself can synthesize CRH (pCRH), with its secretion levels

rising sharply during late pregnancy and showing a positive correlation with maternal HPA axis activity. Studies have found that the exacerbation of maternal depressive symptoms during late pregnancy is significantly associated with elevated pCRH levels, and the increase in pCRH further mediates enhanced cortisol responsiveness in the offspring, suggesting that the placental CRH system serves as a crucial bridge linking maternal emotional state to fetal neuroendocrine programming [3].

In addition to the HPA axis, other neuroendocrine pathways are also involved in mood regulation during late pregnancy. For instance, progesterone (P4) secreted by the placenta peaks in late pregnancy, which exerts an anxiolytic effect by modulating the function of neurotransmitters such as γ -aminobutyric acid (GABA) through its action on progesterone receptors in the central nervous system. Furthermore, the elevation of maternal oxytocin levels in late pregnancy not only promotes uterine contractions and lactation preparation but also enhances maternal emotional affinity and stress coping capacity by acting on the limbic system (e.g., amygdala, hippocampus). However, when maternal emotional stress persists, the balance of these neuroendocrine pathways is disrupted.

4.2 Immune System and Emotional Regulation

During the third trimester, the maternal immune system enters a unique state of "immune tolerance" to allow the semi-allogeneic fetus to develop normally in utero. The maintenance of this immune state depends on the reorganization of immune cell subsets and the balance of cytokine networks. However, emotional stress during late pregnancy (e.g., anxiety, depression) can significantly disrupt adaptive regulation of the immune system, leading to immune dysfunction and subsequently affecting the biological basis of emotional regulation.

Multiple studies have demonstrated that maternal emotional disorders in the third trimester are closely associated with abnormal expression of placental immune-related genes. For instance, an RNA sequencing study of full-term placentas revealed that maternal anxiety or depression during pregnancy significantly downregulates the expression of genes related to T-cell regulation, interleukin signaling pathways, and innate immune responses in placental tissues, including key immune molecules such as CD46, CD15, and CD8 α/β . These dysregulated gene expressions may disrupt the placental immune-tolerant microenvironment, increasing maternal immune rejection risks toward the fetus, while also influencing maternal emotional states through immunoneuroendocrine interactions. Additionally, maternal emotional stress in the third trimester leads to elevated levels of pro-inflammatory cytokines (e.g., IL-6, TNF- α) and reduced levels of anti-inflammatory cytokines (e.g., IL-10) in peripheral blood. This pro-inflammatory state is not only correlated with the onset and progression of emotional disorders but may also affect fetal immune system development via the placenta.

Epigenetic regulation of immune cells also serves as a critical mechanism for the interaction between emotional regulation and the immune system during late pregnancy. Studies have revealed that maternal emotional stress in late pregnancy can alter the DNA methylation status of immune cells, thereby affecting their functional activity. For instance, in pregnant women with multiple sclerosis (MS), CD4 $^+$ and CD8 $^+$ T cells exhibit significant enrichment of DNA methylation changes associated with emotional stress in immune regulatory and inflammation-related genes. These epigenetic alterations persist postpartum, suggesting long-term effects of emotional stress on the immune system. Additionally, the epigenetic state of placental immune cells (such as trophoblast cells and decidual macrophages) is also modulated by maternal emotional states.

4.3 Genetic and Epigenetic Influences

Genetic factors provide the background for individual differences in the biological basis of

emotional regulation during late pregnancy. Multiple studies have shown that genetic polymorphisms associated with neurotransmitter metabolism, HPA axis function, and immune regulation may influence maternal susceptibility to emotional stress during late pregnancy. For example, carriers of the short allele of the serotonin transporter gene (5-HTTLPR) are more prone to anxiety or depressive symptoms during late pregnancy, which may be related to dysfunction of the serotonin system. Additionally, polymorphisms in the glucocorticoid receptor gene (NR3C1) can affect the efficiency of negative feedback regulation of the HPA axis. Maternal carriers of specific alleles are more likely to experience elevated cortisol levels and difficulties in emotional regulation during late pregnancy.

Epigenetic regulation serves as a critical link in the interaction between environmental factors (including emotional stress) and genetic background, playing a dynamic regulatory role in late pregnancy emotional regulation. DNA methylation, one of the most extensively studied epigenetic mechanisms, regulates gene expression by altering the methylation status of gene promoter regions. In a study of pregnant women with recurrent pregnancy loss (RPL), significant hypomethylation was observed in the enhancer regions of imprinted genes such as CPA4 and PRDM16 in placental tissues, leading to upregulated expression of these genes and subsequently affecting placental function and maternal emotional state. Additionally, histone modifications (e.g., acetylation and methylation) are also involved in the epigenetic regulation of late pregnancy emotional regulation.

Non-coding RNAs (such as microRNAs and long non-coding RNAs, lncRNAs) also serve as crucial epigenetic regulators in late pregnancy mood regulation. Exosomes secreted by the placenta are rich in microRNAs, which can act on target cells of both the mother and fetus through the bloodstream to modulate gene expression. Additionally, metabolites from the maternal gut microbiota (e.g., short-chain fatty acids) can influence the function of the HPA axis and mood states by regulating microRNA expression in host cells.

4.4 Neuroimaging Features (Activation of Brain Regions Such as the Amygdala and Prefrontal Cortex)

Neuroimaging techniques have provided direct evidence for elucidating the brain mechanisms underlying emotional regulation during late pregnancy. The amygdala, as the core brain region for emotional processing, exhibits structural and functional changes closely associated with emotional regulation in late pregnancy. Studies indicate that maternal anxiety or depressive symptoms during late pregnancy are correlated with hyperactivation of the amygdala, which may lead to amplified emotional responses and impaired regulation. Additionally, significant alterations occur in the functional connectivity between the maternal amygdala and the prefrontal cortex (PFC) during late pregnancy. The PFC, as a higher-level center for emotional regulation, exerts top-down regulatory inhibition on amygdaloid hyperactivity. However, emotional stress during late pregnancy can weaken this functional connection, resulting in diminished emotional regulation capacity.

In addition to the amygdala and prefrontal cortex, the hippocampus also plays a significant role in emotional regulation during late pregnancy. The hippocampus is not only involved in memory processing but also influences emotional stress responses by modulating the negative feedback of the HPA axis. Maternal emotional stress during late pregnancy can lead to hippocampal volume reduction, decreased neurogenesis, and impaired synaptic plasticity, which are closely associated with difficulties in emotional regulation. Furthermore, neuroimaging studies have revealed that maternal emotional states during late pregnancy are correlated with the structural development of the fetal brain.

4.5 Regulatory Role of the Placenta-Gut Microbiota Axis

The placenta-gut microbiota axis is a novel biological mechanism recently discovered to regulate late-pregnancy mood, which influences the biological processes of mood regulation through bidirectional signaling between gut microbiota, placental function, and the central nervous system. As the host's "second genome," the composition and metabolic activity of gut microbiota undergo significant changes during late pregnancy to adapt to the physiological demands of gestation. However, emotional stress in late pregnancy can lead to gut microbiota dysbiosis, which subsequently affects placental function and central mood regulation through multiple pathways.

The gut microbiota influences placental function and emotional regulation through metabolic products such as short-chain fatty acids and tryptophan metabolites. Studies have found that pregnant rats exposed to CUMS exhibited significantly reduced abundance of Lactobacillaceae in their offspring's intestines, while the abundance of Helicobacteriaceae was markedly increased. Concurrently, the offspring showed decreased levels of short-chain fatty acids in plasma and reduced BDNF expression in the hippocampus, manifesting depressive-like behaviors. Additionally, serotonin (accounting for approximately 90% of the total serotonin in the human body), metabolized from tryptophan by the gut microbiota, can cross the blood-brain barrier to affect the function of the central serotonin system, thereby regulating mood. Dysbiosis of the gut microbiota caused by emotional stress during late pregnancy may reduce serotonin synthesis, thereby exacerbating mood disorders.

As the critical interface between the mother and fetus, the placenta's functional state is also regulated by gut microbiota. Studies have found that maternal gut microbiota dysbiosis can lead to downregulation of placental HSD11B2 expression, increasing maternal glucocorticoid transfer to the fetus, thereby affecting fetal neural development and emotional regulation. Additionally, the placenta itself may harbor resident microbiota, whose compositional changes may directly influence the placental immune status and endocrine function, thereby participating in late pregnancy emotional regulation.

The regulatory role of the placenta-gut microbiota axis is also reflected in its impact on epigenetic mechanisms. Studies have found that probiotic supplementation during pregnancy (e.g., *Lactobacillus plantarum*) can increase the level of benzylation of H3K27 in astrocytes through its metabolite sodium benzoate, thereby promoting the expression of the *Cxcl16* gene and improving neurodevelopmental abnormalities in offspring caused by maternal emotional stress. Additionally, the gut microbiota can influence the gene expression networks of the placenta and central nervous system by regulating microRNA expression, thereby modulating emotional states.

In conclusion, the biological basis of emotional regulation during late pregnancy constitutes a complex multisystem, multi-level network involving neuroendocrine, immune, genetic and epigenetic, neuroimaging, and placenta-gut microbiota axis dimensions. These biological mechanisms interact to form the core of socio-psychobiological interactions, collectively influencing maternal emotional regulation capacity and fetal developmental trajectories during late pregnancy. A deeper understanding of these biological foundations not only aids in elucidating the pathogenesis of late-pregnancy mood disorders but also provides scientific evidence for developing emotion regulation intervention strategies targeting biological targets.

5. Integrated Model of Social-Psychological-Biological Interaction

The socio-psychobiological interaction model of emotional regulation in late pregnancy emphasizes that social environment, psychological processes, and biological foundations are not isolated entities, but rather dynamically and bidirectionally shape an individual's emotional regulation capacity through feedback mechanisms. This framework's theoretical basis originates

from the "biopsychosocial model" in developmental psychopathology, but for the specific context of late pregnancy, it further highlights the unique characteristics of the fetal-maternal system, early intergenerational transmission effects, and the nested structure of multi-level factors.

From a societal perspective, the external ecological environment for emotional regulation in late pregnancy comprises family support systems (e.g., marital attachment, intercultural emotional communication patterns), sociocultural norms, healthcare resource accessibility, and social media usage. For instance, the quality of marital emotional interaction not only directly influences the emotional experience of pregnant women but also indirectly affects their emotional regulation processes by altering psychological cognition (e.g., self-efficacy) and biological stress responses (e.g., cortisol levels). The sociocultural context further shapes the selection of emotional regulation strategies by shaping pregnant women's cognitive evaluation of the "ideal mother" role.

The core elements of the psychological dimension encompass cognitive appraisal, emotional regulation strategies (individual and interpersonal), personality traits, fetal attachment, and emerging strategies such as mindfulness. Cognitive appraisal serves as a mediating process in emotion generation, acting as a critical bridge between social environment and biological responses: a pregnant woman's perception of social support directly influences her emotional arousal level, thereby modulating the activity of the neuroendocrine system. The application of emotional regulation strategies represents the core function of the psychological dimension. For instance, the effective use of cognitive reappraisal strategies not only reduces subjective emotional distress but also promotes the regulatory function of the prefrontal cortex by decreasing excessive activation of the amygdala, thereby forming a positive psychobiological cycle. Notably, fetal attachment, as a unique psychological connection during the third trimester, affects the pregnant woman's motivation for emotional regulation—the strong emotional bond with the fetus may encourage the pregnant woman to more actively seek social support or adopt adaptive regulation strategies to maintain emotional stability, thereby providing a favorable intrauterine environment for the fetus.

The biological mechanisms involve the neuroendocrine system, immune system, genetic and epigenetic regulation, as well as neuroimaging characteristics. During the third trimester, the neuroendocrine system of pregnant women is in a highly sensitive state. Significant fluctuations in estrogen and progesterone levels directly affect the function of neurotransmitters such as serotonin and dopamine, thereby altering the activity of brain regions involved in emotional regulation. The placenta, as a critical biological interface between the mother and the fetus, not only regulates the transfer of maternal cortisol to the fetus but may also influence fetal neurodevelopment through epigenetic mechanisms (e.g., DNA methylation), thereby exerting long-term effects on the emotional regulation capacity of offspring. Additionally, changes in the composition of the gut microbiota (e.g., the ratio of Bacteroidetes to Firmicutes) may indirectly participate in the emotional regulation process by affecting neurotransmitter synthesis and immune-inflammatory responses through the gut-brain axis.

The interactions among these three factors manifest at multiple levels: Firstly, social environmental factors can mediate biological responses through psychological processes—for instance, a lack of social support may lead pregnant women to develop negative cognitive evaluations, which in turn activates the HPA axis, increases cortisol secretion, and over time may result in remodeling of the neuroendocrine system. Secondly, biological factors can also restrict or facilitate the use of psychological strategies—for example, dysfunction of the placenta-gut microbiota axis may elevate levels of inflammatory factors, triggering depression and thereby reducing the motivation of pregnant women to employ positive strategies such as cognitive reappraisal. Lastly, the interaction between psychological processes and biological factors can also inversely influence the social environment—for example, pregnant women with poor emotional regulation may be more prone to conflicts with their partners, thereby worsening the family support

system and creating a vicious cycle. This multi-level interaction ultimately determines the overall efficacy of emotional regulation in late pregnancy and provides a more comprehensive perspective for understanding the mechanisms underlying mood disorders.

6. Intervention Strategies for Emotional Regulation in Late Pregnancy

6.1 Psychological Intervention Strategies (Cognitive Behavioral Therapy, Mindfulness Intervention, etc.)

Psychological intervention strategies for emotional regulation in late pregnancy primarily revolve around cognitive behavioral therapy (CBT), mindfulness interventions, and related derivative techniques. The core objective is to improve the psychological state of pregnant women by adjusting cognitive patterns and enhancing emotional awareness and regulation. As a classical psychological intervention method, CBT has demonstrated significant efficacy in emotional regulation during late pregnancy. For pregnant women with a history of primary infertility, group CBT interventions can effectively reduce perceived stress, anxiety, and depression levels while improving quality of life, with these effects persisting post-intervention. Additionally, online CBT-based interventions (e.g., the digital biopsychosocial CBT program in the BienGestar study) combine techniques such as cognitive restructuring and behavioral activation to not only reduce pregnancy-related anxiety and depressive symptoms but also enhance psychological well-being, with effects persisting postpartum. Notably, CBT interventions are increasingly evolving toward digitalization and personalization. For instance, the Mothers and Babies Personalized Intervention (MB-P) provides real-time stress management and mindfulness content based on physiological monitoring or self-reported stress levels, significantly reducing postpartum depression symptoms and perceived stress within three months while enhancing behavioral activation, decentralized thinking, and emotional regulation. This personalized intervention can also be tailored according to the adverse childhood experiences (ACEs) of pregnant women. For example, enhancing trauma-informed content for pregnant women with ACEs can further optimize intervention outcomes .

Mindfulness intervention, as another important psychological intervention strategy, also plays a crucial role in emotional regulation during the third trimester of pregnancy. Studies have shown that mindfulness-based cognitive therapy (MBCT) can effectively reduce depressive and anxious symptoms in pregnant women, improve their emotional regulation strategies, and enhance psychological well-being, with effects persisting for one month post-intervention. For pregnant women at risk of preterm birth, brief mindfulness interventions (e.g., a 6-week mindfulness course) can significantly reduce perceived stress, pregnancy-specific stress, trait anxiety, and depressive levels, while improving mindfulness skills. These effects remain sustained at 2 and 7 months post-intervention. Additionally, mindfulness intervention can positively influence fetal neurodevelopment by improving maternal emotional regulation abilities. For instance, infants of mothers who participated in prenatal mindfulness interventions exhibited healthier autonomic nervous system responses and self-regulatory behaviors at 6 months of age.

In addition to traditional cognitive behavioral therapy (CBT) and mindfulness interventions, emerging psychological techniques are increasingly being applied to emotional regulation during late pregnancy. For instance, online interventions based on dialectical behavioral therapy (DBT) focus on emotion recognition and regulation, effectively improving pregnant women's emotional regulation abilities and mental health. The interpersonal conflict cognitive reappraisal intervention guides pregnant women to view interpersonal conflicts from a third-party perspective, enhancing the accessibility of their emotional regulation strategies and thereby reducing depressive symptoms, with particularly significant effects observed in those with high attachment anxiety. These intervention strategies not only enrich the methods of emotional regulation during late pregnancy

but also provide more options for pregnant women with diverse needs.

6.2 Biological Targeted Interventions (Neural Modulation, Hormonal Regulation, etc.)

Biological targeted interventions primarily improve emotional regulation in late pregnancy by modulating neural activity, hormone levels, and related physiological indicators. As a non-invasive approach, neuromodulation techniques have demonstrated potential in emotional regulation. For instance, transcranial direct current stimulation (tDCS) enhances emotional regulation by regulating activity in the ventromedial prefrontal cortex. This technique has been applied in the treatment of adolescent mood disorders and is expected to be extended to emotional regulation in late pregnancy. Additionally, neurofeedback therapy, which utilizes feedback mechanisms to help individuals regulate physiological responses, has been proven effective in improving emotional regulation and social skills in children with autism. Its underlying principles may also apply to emotional regulation in pregnant women during late pregnancy.

Hormonal regulation plays a significant role in emotional regulation during the third trimester of pregnancy. During this period, substantial changes in maternal hormone levels occur, such as elevated cortisol levels, which may lead to mood fluctuations. Studies have shown that mindfulness interventions can reduce maternal stress levels by modulating the circadian rhythm of cortisol secretion. Additionally, the placenta-gut microbiota axis, as an emerging regulatory mechanism, may exert important effects on emotional regulation by influencing neurotransmitter synthesis and immune-inflammatory responses. For instance, nutritional and exercise interventions during pregnancy can improve gut microbiota composition and optimize placental function, thereby regulating maternal emotional states. Although there are currently limited studies directly addressing hormonal regulation in late pregnancy, relevant foundational research provides a theoretical basis for future clinical applications.

6.3 Social Support Integration Interventions (Family Interventions, Digital Interventions, etc.)

Social support integration interventions emphasize providing comprehensive emotional support for late-term pregnant women by integrating family, social, and digital resources. The family support system plays a central role in emotional regulation, as marital attachment and emotional interactions directly influence the emotional state of pregnant women. Studies have shown that family-based interventions for pregnant women (e.g., the Circle of Security Parenting program) can effectively enhance maternal sensitivity, improve mother-infant relationships, and thereby promote emotional regulation in pregnant women. Additionally, differences in cross-cultural family emotional communication patterns may also affect intervention efficacy. For instance, in Pakistan, CBT interventions significantly reduced the risk of perinatal intimate partner violence by improving marital relationship quality and social support.

Digital interventions, as an emerging social support modality, demonstrate significant potential in emotional regulation during late pregnancy. For instance, social media-based CBT interventions (e.g., the IMAGINE project) effectively reduce depressive symptoms in young pregnant women by creating supportive communities that provide non-judgmental support and peer companionship. Meanwhile, mHealth interventions deliver psychological education, behavioral monitoring, and real-time support through mobile applications, significantly improving maternal emotional states. The Motherly app, for example, integrates CBT with behavioral activation techniques, not only alleviating pregnancy-related depression but also enhancing sleep quality and overall life quality. Additionally, virtual reality (VR) technology has been applied to emotional regulation interventions. Prenatal affective cognitive training (PACT), for example, utilizes VR scenarios to help pregnant women correct cognitive biases toward infant cues, thereby preventing postpartum depression.

Social support integration interventions also emphasize cross-cultural and individualized needs. For instance, for pregnant women in Pakistan, CBT interventions effectively improved their anxiety symptoms and functional difficulties by adapting content to local cultural contexts. Meanwhile, for pregnant women with special needs (e.g., those suspected of fetal malformations), Internet-based emotion-focused CBT (IECBT) significantly reduced their anxiety and stress levels by incorporating spousal participation and booster sessions. These intervention strategies not only enhance the accessibility of social support but also ensure the effectiveness and adaptability of the interventions.

7. Conclusion

This review systematically reviews the research progress on emotional regulation mechanisms in late pregnancy from a socio-psychobiological interaction perspective, revealing the dynamic associations among social, psychological, and biological factors in the emotional regulation process and their profound impacts on maternal and child health. Existing interaction models predominantly rely on static correlation analysis, lacking mechanistic explanations for dynamic regulatory processes. Methodologically, there are issues such as sample bias and the use of single assessment tools. Current interventions primarily focus on psychological strategies (e.g., mindfulness, CBT), with limited exploration of biologically targeted interventions (e.g., neuromodulation). Additionally, the evaluation of intervention effects is often limited to short-term symptom relief, lacking follow-up on long-term maternal and child health outcomes (e.g., cognitive development in children). Although digital interventions hold potential, insufficient research on technology acceptance and cultural adaptability has constrained their widespread application. Future studies should further break down disciplinary barriers and promote interdisciplinary collaboration to achieve a comprehensive understanding of late pregnancy emotional regulation mechanisms, ultimately improving maternal and child health outcomes.

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References

- [1] Javadekar Archana, Karmarkar Arpita, Chaudhury Suprakash, et al. *Biopsychosocial correlates of emotional problems in women during pregnancy and postpartum period*[J]. *Industrial Psychiatry Journal*, 2023, 32(Suppl 1): S141-S146. doi:10.4103/ipj.ipj_225_23.
- [2] Frigerio Alessandra, Molteni Massimo. *Intensity of Maternal Anxiety and Depressive Symptoms in Pregnancy Is Associated with Infant Emotional Regulation Problems*[J]. *International Journal of Environmental Research and Public Health*, 2022, 19(23).doi:10.3390/ijerph192315761.
- [3] Rinne Gabrielle, Somers Jennifer, Ramos Isabel, et al. *Increases in maternal depressive symptoms during pregnancy and infant cortisol reactivity: Mediation by placental corticotropin-releasing hormone*[J]. *Development and Psychopathology*, 2022, 35(4): 1997-2010. doi:10.1017/S0954579422000621.
- [4] Sancho-Rossignol Ana, Schilliger Zoe, Cordero Mar ú, et al. *The Association of Maternal Exposure to Domestic Violence During Childhood With Prenatal Attachment, Maternal-Fetal Heart Rate, and Infant Behavioral Regulation*[J]. *Frontiers in Psychiatry*, 2018, 9. 358. doi:10.3389/fpsy.2018.00358.
- [5] Giles Lauren, Khoury Jennifer. *Emotion regulation during pregnancy: A pathway from maternal childhood maltreatment to perinatal mental health*[J]. *Journal of Affective Disorders*, 2025, 385. 119417. doi:10.1016/j.jad.2025.119417.
- [6] Nyman Tristin, Pegg Samantha, Kiel Elizabeth, et al. *Perceived social support moderates neural reactivity to emotionally valenced stimuli during pregnancy*[J]. *Psychophysiology*, 2020, 57(11): e13647. doi:10.1111/psyp.13647.

- [7] Mor Shirly, Sela Yaron, Lev-Ari Shahar. *Postpartum Mothers' Mental Health in a Conflict-Affected Region: A Cross-Sectional Study of Emotion Regulation and Social Support*[J]. *Journal of Clinical Medicine*, 2025, 14(4).doi:10.3390/jcm14041244.
- [8] Ghorbani-Marghmaleki Fatemeh, Mohebbi-Dehnavi Zahra, Beigi Marjan. *Investigating the relationship between cognitive emotion regulation and the health of pregnant women*[J]. *Journal of Education and Health Promotion*, 2019, 8. 175. doi:10.4103/jehp.jehp_10_19.
- [9] Carandang Rogie, Epel Elissa, Radin Rachel, et al. *Perceived Stress and Depressive Symptoms Are Associated With Emotional Eating but Not Nutritional Intake During Pregnancy: A Prospective Cohort Study*[J]. *Journal of Midwifery & Women's Health*, 2023, 69(1): 64-70. doi:10.1111/jmwh.13537.
- [10] Coó Soledad, Garc ía María, Prieto Fernanda, et al. *The role of interpersonal emotional regulation on maternal mental health*[J]. *Journal of Reproductive and Infant Psychology*, 2020, 40(1): 3-21. doi:10.1080/02646838.2020.1825657.
- [11] Greene Carolyn, McCoach D, Briggs-Gowan Margaret, et al. *Associations among childhood threat and deprivation experiences, emotion dysregulation, and mental health in pregnant women*[J]. *Psychological trauma*, 2021, 13(4): 446-456. doi:10.1037/tra0001013.
- [12] Liu Shaofei, Lin Qiaoxuan, Feng Yonghsen, et al. *The protective role of social support on prenatal depression among pregnant women of advanced maternal age: a Three-Trimester follow-up study in China*[J]. *Journal of Obstetrics and Gynaecology*, 2022, 42(8): 3456-3463. doi:10.1080/01443615.2022.2135986.
- [13] Wohrer Fiona, Ngo Helen, DiDomenico Jared, et al. *Potentially modifiable risk and protective factors affecting mental and emotional wellness in pregnancy*[J]. *Frontiers in Human Neuroscience*, 2024, 18. 1323297. doi:10.3389/fnhum.2024.1323297.
- [14] Fish-Williamson Adi, Hahn-Holbrook Jennifer, Hobbs Mark, et al. *Prenatal antibiotic exposure in pregnancy and early childhood socioemotional development*[J]. *JCPP Advances*, 2022, 2(2): e12066. doi:10.1002/jcv2.12066.
- [15] İlkyaz Kaya Yıldırım, Gülay Dirik. *Targeting emotion in the perinatal period: a systematic review of emotion-focused and emotion regulation-based interventions*[J]. *Psychology and Health*, 2025, 1-34. doi:10.1080/08870446.2025.2572474.
- [16] DiPietro Janet, Kivlighan Katie, Voegtline Kristin, et al. *It Takes Two: An antenatal to postnatal RDoC framework for investigating the origins of maternal attachment and mother-infant social communication*[J]. *Development and Psychopathology*, 2021, 33(5): 1539-1553. doi:10.1017/s0954579421000997.