# **Environmental risk factors, protective factors, and biomarkers for postpartum depressive symptoms: an umbrella review**

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**Abstract (169/170 words)**

We performed an umbrella review on environmental risk/protective factors and biomarkers for postpartum depressive symptoms to establish a hierarchy of evidence. We systematically searched PubMed, Embase, and the Cochrane Database of Systematic Reviews from inception until 12 January 2021. We included systematic reviews providing meta-analyses related to our research objectives. Methodological quality was assessed by AMSTAR 2, and the certainty of evidence was evaluated by GRADE. This review was registered in PROSPERO (CRD42021230784). We identified 30 articles, which included 45 environmental risk/protective factors (154594 cases, 7302273 population) and 9 biomarkers (2018 cases, 16757 population). The credibility of evidence was convincing (class I) for antenatal anxiety (OR 2.49, 1.91-3.25) and psychological violence (OR 1.93, 1.54-2.42); and highly suggestive (class II) for intimate partner violence experience (OR 2.86, 2.12-3.87), intimate partner violence during pregnancy (RR 2.81, 2.11-3.74), smoking during pregnancy (OR 2.39, 1.78-3.2), history of premenstrual syndrome (OR 2.2, 1.81-2.68), any type of violence experience (OR 2.04, 1.72-2.41), primiparity compared to multiparity (RR 1.76, 1.59-1.96), and unintended pregnancy (OR 1.53, 1.35-1.75).

**Keywords**

* Postpartum depressive symptoms
* Environmental risk and protective factors
* Biomarkers
* Umbrella review

**Main text**

**1. Introduction**

Postpartum depression is defined as a major depressive episode occurring within four weeks after delivery, which is encompassed by the “with peripartum onset” specifier in the DSM-5. In the eleventh revision of the ICD, postpartum depression is included in “mental or behavioral disorders associated with pregnancy, childbirth or the puerperium.” In the clinical and research settings, however, postpartum depression is typically defined as the presence of depressive symptoms occurring up to 12 months after birth rather than the DSM or ICD definition (Stewart and Vigod, 2016). As one of the most common complications of pregnancy, the prevalence of postpartum depression is estimated to be approximately 9.2-19.2% (Banti et al., 2011; Gavin et al., 2005), with variability arising from different diagnostic criteria and population-specific factors (O'Hara and McCabe, 2013). The disorder has a profound impact on the quality and function of the mother's life (Field, 2010; Salmela-Aro et al., 2001), affecting her children's behavior, cognitive development, and physical health (Goodman et al., 2011; Gump et al., 2009) and can lead to potentially fatal consequences for both the mother and her children (Gressier et al., 2017; Pearson et al., 2013).

Because of this high personal, clinical, and societal burden of postpartum depression, preventive approaches have been investigated. Understanding risk and protective factors associated with postpartum depression is a prerequisite to advancing preventive care (Jones, 2021). Accordingly, numerous primary studies have explored genetic and environmental factors, as well as biomarkers that might reflect their effects, showing that postpartum depression is caused by a complex interaction of genetic predispositions and environmental factors (Mahon et al., 2009; Payne and Maguire, 2019; Robertson et al., 2004; Segman et al., 2010). Although these studies have been summarized by meta-analyses, these are typically restricted to a single factor and do not carefully examine important biases including publication bias or reporting bias (Ioannidis, 2005, 2008). Therefore, the consistency and magnitude of environmental factors or biomarkers associated with postpartum depression are undetermined. Meanwhile, given that most previous studies used questionnaires such as the Edinburgh Postnatal Depression Scale (EPDS) rather than the DSM or ICD diagnosis, it would be more accurate to note that they investigated postpartum depressive ‘symptoms’ rather than ‘disorder.’ Moreover, some previous meta-analyses included less objective diagnostic methods such as self-reports or set too liberal cutoffs for determining postpartum depressive symptoms, which may have resulted in potential false positives and exaggerated effects. In this regard, this umbrella review aimed to provide a bird's eye view on environmental risk factors, protective factors, and biomarkers for postpartum depressive symptoms by applying the state-of-the-art hierarchical system and presenting detailed underlying mechanisms.

**2. Methods**

*2.1. Protocol, registration, and study design*

We performed an umbrella review of systematic reviews and meta-analyses in compliance with the updated PRISMA guidelines (Appendix pp 5-7) (Page et al., 2021). This review is registered with PROSPERO, number CRD42021230784, which is available online. The screening process, data extraction, and methodological appraisal of eligible articles were conducted independently by two investigators (JHK and SL), and any disagreement was resolved through discussion among four authors (JHK, JYK, SL, and JIS).

*2.2. Search strategy and eligibility criteria*

We systematically searched PubMed, Embase, and the Cochrane Database of Systematic Reviews from database inception to Jan 12, 2021, without any language restrictions. We used predetermined search terms including "postpartum", "depress\*", and "meta-analysis", and full search strategies for each database are presented in appendix p 8. To find eligible articles among the searched articles, each investigator screened titles, abstracts, and full texts in order. We also manually searched the references of relevant articles (Figure 1).

We included systematic reviews providing meta-analyses that examined associations between postpartum depressive symptoms and environmental risk factors, protective factors, or biomarkers. The definitions of environmental risk factor, protective factor, and biomarker are presented in appendix p 9. Since most meta-analyses used questionnaires such as the EPDS rather than DSM or ICD criteria, we investigated ‘postpartum depressive symptoms’ that occurred within 12 months after childbirth. We included studies that used the validated diagnostic methods for determining postpartum depressive symptoms including not only DSM (any edition), ICD (any edition), and medical records but also EPDS, the Center for Epidemiologic Studies Depression scale (CES-D), Beck Depression Inventory (BDI), etc.

We excluded articles that did not study environmental risk factors, protective factors, or biomarkers for postpartum depressive symptoms; articles that did not provide meta-analyses; articles that did not provide sufficient data for the re-analysis of a meta-analysis (i.e., individual study estimates or the data to calculate them). We also excluded non-human studies, purely genetic studies, primary studies, and conference abstracts. If more than one meta-analysis covered the same topic, we prioritized the one with the largest number of individual studies, then the most recent one, and lastly, the one with the largest number of cases with postpartum depressive symptoms. The list of articles excluded at the full-text screening stage is presented in appendix pp 13-18.

*2.3. Data extraction*

From each eligible meta-analysis, we extracted the following data: the names of the authors; publication year; environmental risk factors, protective factors, or biomarkers; operationalization of depressive symptoms and applied cutoff for each individual study if available; number of cases with postpartum depressive symptoms and total study population; maximally adjusted individual study estimates and corresponding 95% confidence intervals (95% CIs); metrics used in the original analyses (e.g. odds ratio [OR], relative risk [RR], Hedge’s g); and study designs of individual studies (e.g. cohort, case-control, cross-sectional).

*2.4. Data analysis*

*2.4.1. Main data analysis*

We conducted a series of statistical tests to examine the robustness and consistency of data in accordance with previous umbrella reviews (Belbasis et al., 2015; Bellou et al., 2017; Kim et al., 2020; Kim et al., 2019) and recent guidance for umbrella review (Fusar-Poli and Radua, 2018). We re-analyzed each eligible meta-analysis based on extracted individual study estimates, using metrics used in the original meta-analysis. We calculated the summary effect estimate, corresponding 95% CI, and p values under both random and fixed effects models. We further assessed whether p values < 0.001 or 0.000001 (Ioannidis et al., 2011; Sterne and Davey Smith, 2001). To evaluate heterogeneity, we performed Cochran's Q test and calculated the *I²* statistic (*I²* > 50% indicates high heterogeneity) (Cochran, 1954). We assessed the existence of small study effects (i.e., larger studies have significantly more conservative results than smaller studies) with the regression asymmetry test proposed by Egger and colleagues (Egger et al., 1997), and small study effects were noted at Egger p value < 0.1. We estimated the 95% prediction interval, the range in which we expect the effect of association would lie for 95% of future studies (Higgins et al., 2009). We performed p-curve analysis and assessed the distribution of statistically significant p values to detect publication bias or p-hacking among the individual studies (Simonsohn et al., 2014a, b), and we denoted a set of individual studies to have evidential value when the possibility of selective reporting was ruled out (p value for the right-skewness test for the half curve < 0.05 or p value for the right-skewness test < 0.1 for both the half and full curve) (Simonsohn et al., 2014b). We also performed random-effects meta-analyses under 5%, 10%, 15%, and 20% credibility ceilings to account for the potential methodological limitations of observational studies that might result in spurious significance (Papatheodorou et al., 2015; Salanti and Ioannidis, 2009).

The methodological quality of each eligible article was assessed using A Measurement Tool to Assess Systematic Reviews 2 (AMSTAR 2) by two independent investigators (JHK and SL) and any disagreements were resolved by consensus (Shea et al., 2017). The overall certainty of the estimate was evaluated based on the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) method by two authors (JHK and JYK), and any disagreements were resolved by consensus (Balshem et al., 2011). Because all included individual studies were observational studies, the decision for the certainty of evidence started at 'low' and downgraded to 'very low' when at least one reason to downgrade was identified, while upgraded to 'moderate' when some reason was found to upgrade such as large effect size.

*2.4.2. Sensitivity analyses*

We performed sensitivity analyses of the validated cutoff scores for determining postpartum depressive symptoms by excluding individual studies that used lower cutoffs than the validated ones, which may lead to false positive and exaggerated effects. The validated cutoffs we used for each included operationalization of depressive symptoms are presented in appendix p 10. We also conducted sensitivity analyses of cohort studies (retrospective or prospective), prospective cohort studies, and study estimates adjusted for at least one confounder to further assess the robustness of the evidence. All sensitivity analyses were performed for associations graded as providing convincing or highly suggestive evidence. All statistical tests were two-sided and statistical significance was set at p < 0.05. All statistical analyses were performed by R version 4.0.4 and its packages.

*2.5. Determining the credibility of evidence*

Referring to the classification system of recent umbrella reviews (Belbasis et al., 2015; Bellou et al., 2017; Kim et al., 2020; Kim et al., 2019), we classified the identified associations into five classes by their level of credibility, based on the results of our statistical analyses – convincing (class I), highly suggestive (class II), suggestive (class III), weak (class IV), and not significant (NS) (Table 1). Criteria for classifying the level of evidence included p value under a random-effects model, number of cases with postpartum depressive symptoms, the p value of the largest study, the *I²* statistic, small study effects, results of the p-curve analysis, the 95% prediction interval, and a random-effects p value under a 10% credibility ceiling.

**3. Results**

*3.1. Search results*

From database inception to Jan 12, 2021, we identified 454 articles of which only 30 met the inclusion criteria (Figure 1). Among the 30 articles, 54 unique meta-analyses were identified (45 environmental risk/protective factors and nine biomarkers; Table 2, Appendix p 19, 22-24, 28-122) (Azami et al., 2019a; Azami et al., 2019b; Bacchus et al., 2018; Beydoun et al., 2012; Cao et al., 2020; Chen et al., 2019; Dachew et al., 2021; Dadi et al., 2020; de Paula Eduardo et al., 2019; Desta et al., 2021; Falah-Hassani et al., 2015; Grigoriadis et al., 2019; Howard et al., 2013; Kang et al., 2020; Kountanis et al., 2020; Lin et al., 2017; Minaldi et al., 2020; Moameri et al., 2019; Molyneaux et al., 2014; Necho et al., 2020; Qiu et al., 2020; Tan et al., 2021; Tokumitsu et al., 2020; Tolossa et al., 2020; Wang et al., 2018; Yang et al., 2020; Yargawa and Leonardi-Bee, 2015; Ye et al., 2020; Zhang et al., 2019; Zhu et al., 2019).

*3.2. Environmental risk factors and protective factors*

The 45 meta-analyses of environmental risk/protective factors were based on 154594 cases with postpartum depressive symptoms (median 1031 per meta-analysis, interquartile range [IQR] 551-5835, range 89-17954) and included 7302273 total population (median 11758 per meta-analysis, IQR 4437-77838, range 875-2302311). Among them, 34 meta-analyses were based on cohorts, of which, 23 also included case-control or cross-sectional studies. The median number of study estimates was eight (IQR 5-12, range 2-39). Effect metrics were either OR or RR. Among 45 associations, 43 (96%) associations were statistically significant with p<0.05, 35 of 45 (78%) with p<0.001, and 13 of 45 (29%) with p<0.000001. Among 43 statistically significant associations, 25 (58%) included more than 1000 cases with postpartum depressive symptoms. Only 14 of 45 (31%) associations showed no heterogeneity (*I²*<50%). Among 45 associations, three (7%) were not appropriate for Egger’s test since they included less than three individual studies. Subsequently, 30 of 42 (71%) associations presented no small study effect. Further, 39 of 45 (87%) associations suggested no problems in the p-curve analysis, 33 of 45 (73%) retained statistical significance with a 10% credibility ceiling, and the 95% prediction interval excluded the null value in 7 of 45 (16%).

Only two environmental risk factors were graded as convincing evidence (class I; Table 2, Figure 2): antenatal anxiety (OR 2.49, 95% CI 1.91-3.25) and psychological violence (OR 1.93, 95% CI 1.54-2.42). Seven were graded as highly suggestive evidence (class II; Table 2, Figure 2): intimate partner violence experience (OR 2.86, 95% CI 2.12-3.87), intimate partner violence during pregnancy (RR 2.81, 95% CI 2.11-3.74), smoking during pregnancy (OR 2.39, 95% CI 1.78-3.2), history of premenstrual syndrome (OR 2.2, 95% CI 1.81-2.68), any type of violence experience (OR 2.04, 95% CI 1.72-2.41), primiparity compared to multiparity (RR 1.76, 95% CI 1.59-1.96), and unintended pregnancy (OR 1.53, 95% CI 1.35-1.75). Remarkably, 4 of 9 (44%) factors with high level of evidence were related to violence against the mother. Other factors included preterm birth, pre-pregnancy obesity, cesarean section (class III), low income, poor social support, and poor marital relationship (class IV). Meanwhile, active husband participation in maternal healthcare/services during pregnancy and postpartum showed protective effects against postpartum depressive symptoms with statistical significance (class IV).

*3.3. Biomarkers*

The nine biomarker meta-analyses covered 2018 cases with postpartum depressive symptoms (median 201 per meta-analysis, IQR 200-215, range 168-404) and 16757 total population (median 1793 per meta-analysis, IQR 1741-1793, range 1432-2375). All nine meta-analyses were based on cohorts, of which, four also included case-control or cross-sectional studies. The median number of study estimates was five (IQR 5-6, range 3-7). Effect metrics were either OR, RR, or Hedge’s g. Among nine associations, only three (33%) were statistically significant with p<0.05, while there was no association with p<0.0001. No association included more than 1000 cases with postpartum depressive symptoms, and only 3 of 9 (33%) associations showed no heterogeneity. All associations were available for Egger’s test and 7 of 9 (78%) showed no small study effect. However, all but one suggested a problem in the p-curve analysis. No association retained statistical significance with a 10% credibility ceiling and excluded the null value in the 95% prediction interval. Accordingly, no association was graded as convincing or highly suggestive evidence (Appendix p 19).

*3.4. AMSTAR 2 quality assessment*

AMSTAR 2 quality assessment was available for all associations. Among 30 articles, 26 reported environmental risk/protective factors and four biomarkers. Of 26 meta-analysis articles on environmental risk/protective factors, only three (11%) were graded as high quality, two (8%) moderate, seven (27%) low, and 14 (54%) critically low. Of four meta-analysis articles on biomarkers, one (25%) was graded as low, and three (75%) were critically low. Among factors with a high level of evidence, only two (intimate partner violence experience and history of premenstrual syndrome) were graded as high quality.

*3.5 Certainty of evidence using the GRADE method*

Certainty of evidence was assessed for each estimate based on the GRADE method (Table 1, Appendix p 19). Out of 45 meta-analyses of environmental risk/protective factors, three (7%) were rated as moderate, 13 (29%) were low, and 29 (64%) were very low. Out of nine meta-analyses of biomarkers, one (11%) was rated as low and eight (89%) were very low. Among the factors with a high level of evidence, only one (antenatal anxiety) was graded as moderate. Detailed information on the decision of certainty of evidence for each estimate is presented in appendix pp 25-27.

*3.6. Sensitivity analyses*

Sensitivity analyses of the validated cutoff scores for meta-analyses with a high level of evidence (class I or II) were conducted. After excluding individual studies that used a lower cutoff than the validated one, 7 of 9 (78%) factors retained their level of evidence: antenatal anxiety (class I), intimate partner violence experience, intimate partner violence during pregnancy, smoking during pregnancy, history of premenstrual syndrome, any type of violence experience, and unintended pregnancy (class II), whereas the rest were downgraded to class III or IV. Sensitivity analyses of 1) cohort (retrospective and prospective), 2) prospective cohort, and 3) adjusted study estimates for meta-analyses with a high level of evidence (class I or II) were also performed. In the cohort sensitivity analyses, five factors retained their level of evidence: antenatal anxiety, psychologic violence (class I), any type of violence experience, primiparity compared to multiparity, and unintended pregnancy (class II), whereas the rest were downgraded to class III or IV, or inappropriate for subgroup analysis since they included fewer than two cohort studies. In the prospective cohort subgroup analysis, the same factors retained the level of evidence except for antenatal anxiety (class I to III). In the sensitivity analyses of adjusted study estimates, which was unavailable for one (intimate partner violence experience), 5 of 8 (63%) factors graded as class II: psychologic violence, intimate partner violence during pregnancy, any type of violence experience, primiparity compared to multiparity, and unintended pregnancy, whereas the rest were downgraded to class III or IV. All statistical details of the sensitivity analyses are presented in appendix pp 20-21.

**4. Discussion**

*4.1. Summary of important results*

To the best of our knowledge, this study is the first umbrella review based on the state-of-the-art evidence grading strategy, which systematically and quantitatively collected and assessed the hierarchy of evidence for environmental risk factors, protective factors, and biomarkers for postpartum depressive symptoms. Only nine associations of environmental risk factors showed evidence of high credibility (antenatal anxiety, psychological violence [class I], intimate partner violence experience, intimate partner violence during pregnancy, smoking during pregnancy, history of premenstrual syndrome, any type of violence experience, primiparity compared to multiparity, and unintended pregnancy [class II]).

*4.1.1 Strength of the present study*

Indeed, there are three previous studies attempted to summarize the evidence on environmental risk factors of postpartum depressive symptoms (Gastaldon et al., 2022; Hutchens and Kearney, 2020; Zhao and Zhang, 2020). However, two reviews (Hutchens and Kearney, 2020; Zhao and Zhang, 2020) did not apply a hierarchical system that can account for several types of biases (Fusar-Poli and Radua, 2018). Meanwhile, Gastaldon et al. (Gastaldon et al., 2022) established a hierarchy of the evidence but reported 12 potential risk factors which is fewer than 45 risk factors identified in our review. We also found two risk factors with convincing evidence (Class I) (antenatal anxiety and psychological violence), whereas Gastaldon et al. found none. It should also be noted that the criteria for convincing evidence (class I) is stricter in our review than the review by Gastaldon et al., given that we used 10% credibility ceilings test, which was introduced in previous umbrella reviews (Kim et al., 2020; Kim et al., 2019), and we also used a novel p-curve analysis to detect p hacking. Lastly, we endeavored to address the underlying biological and/or behavioral mechanisms in detail for each risk factors with high level of evidence (class I and II).

*4.2. Psychological violence, intimate partner violence experience, intimate partner violence during pregnancy, and any type of violence experience*

Various types of violence against the mother (psychological violence (Zhang et al., 2019) [class I]; intimate partner violence experience (Howard et al., 2013), intimate partner violence during pregnancy (Beydoun et al., 2012), and any type of violence experience (Zhang et al., 2019) [class II]) were associated with a higher risk of postpartum depressive symptoms. Of note, psychological violence was downgraded to class III in the sensitivity analysis of the validated cutoff scores, while others were not. Though the underlying mechanism is unclear, given that violence against the mother is a type of stress, stress-related neuroendocrine dysfunction and gene-stress interaction seem to be the most plausible explanations. The former suggests that the unbalanced secretion of glucocorticoids, the final product of the hypothalamic-pituitary-adrenal (HPA) axis, which is activated by a stress response, may affect psychological function, leading to depression (Brummelte and Galea, 2010; Meltzer-Brody, 2011). The latter proposes that reduced activity of brain-derived neurotrophic factors resulting from stressful events may lead to the diminished function of brain regions, including those involved in emotional processing and cognition, and eventually, subsequent changes in mood and depression (Begni et al., 2017; Brunoni et al., 2008; Molendijk et al., 2014). Notably, the majority of factors related to violence against the mother —including class I, II, and also others —had effect sizes larger than two. In this regard, the violence experience of the mother may be a robust predictor of postpartum depressive symptoms despite its somewhat large heterogeneity. These findings emphasize the necessity of screening for domestic and intimate partner violence and promoting maternal mental health.

*4.3. Antenatal anxiety*

Antenatal anxiety (Grigoriadis et al., 2019) provided convincing evidence for increasing the risk of postpartum depressive symptoms with an effect size larger than two (OR 2.64, 95% CI 2.02-3.46), retaining convincing evidence in sensitivity analysis of the validated cutoff scores. Notably, antenatal anxiety showed moderate certainty of evidence according to the GRADE method even though its analysis only contained observational studies. It should be mentioned that the factor is simply anxiety, which represents symptoms rather than the disorder. Indeed, individual studies in the meta-analysis included not only those that used the diagnostic criteria of anxiety disorder but also those that used anxiety questionnaire scores (e.g., state-trait anxiety inventory-trait score itself) or an additional cut-off system (e.g., state-trait anxiety inventory-trait score > 45). Of note, the latter distinguished excessively anxious mothers from those experiencing anxiety of a normal range by setting certain cutoff scores such as one standard deviation above the mean or the top 25th percentile. In terms of anxiety disorders, antenatal social phobia (Coelho et al., 2011), generalized anxiety disorder (Coelho et al., 2011), and panic disorder (Rambelli et al., 2010) are also suggested to be independent risk factors for postpartum depressive symptoms respectively. Although robust biological mechanisms have yet to be identified, it is important to point out that 1) anxiety symptoms are frequently reported in pregnancy and often even considered a typical experience of pregnancy, and 2) problematic anxiety symptoms in pregnancy were not well distinguished from normal anxiety, and thereby the anxiety symptoms of mothers should not simply be considered to be a normal adaptive part of pregnancy.

*4.4. Smoking during pregnancy*

Smoking during pregnancy (Chen et al., 2019) was associated with an increased risk of postpartum depressive symptoms with highly suggestive evidence, retaining the level of evidence in sensitivity analysis of the validated cutoff scores while downgraded to weak in other sensitivity analyses. Regarding its biological mechanisms, it has been proposed that smoking may have anti-estrogenic effects by disrupting endogenous estrogen biosynthesis and bioavailability (Baron, 1984; Ruan and Mueck, 2015), given that women are prone to mood fluctuation during the period when hormone levels (especially sex steroid hormones such as estrogen and progesterone) change rapidly (Schiller et al., 2015). HPA axis activation due to immune system alteration (Lee et al., 2012; McEvoy et al., 2015; Pace and Miller, 2009), increased oxidative stress (Black et al., 2015; Yanbaeva et al., 2007), and nicotine acetylcholine receptors (Philip et al., 2010) induced by smoking are other potential mechanisms. Meanwhile, numerous investigations have been conducted regarding the various smoking cessation patterns and corresponding risk of postpartum depressive symptoms. Salimi et al. (Salimi et al., 2015) reported the odds of postpartum depressive symptoms in women who quit smoking during the final 3 months of pregnancy but resumed after parturition (OR 1.28, 1.06-1.53) and who did not quit at all (OR 1.48, 1.26-1.73) compared to those who quit during the final 3 months of pregnancy and remained non-smokers after parturition. Although using a less rigorous definition of postpartum depression, this finding demonstrates that smoking cessation is important not only before or during pregnancy but also in the postpartum period to prevent postpartum depressive symptoms. In addition, passive smoking should also be avoided (Song et al., 2019). Potential confounders of the association should be accounted for, such as prenatal stressful events which may be associated with both smoking and postpartum depressive symptoms (Kassel et al., 2003; Necho et al., 2020).

*4.5. History of premenstrual syndrome*

History of premenstrual syndrome (Cao et al., 2020) was associated with an increased risk of postpartum depressive symptoms with highly suggestive evidence, retaining the level of evidence in sensitivity analysis of the validated cutoff scores while downgraded to weak in other sensitivity analyses. This association is noteworthy because premenstrual syndrome has a high prevalence of around 70% (Ranjbaran et al., 2017). Regarding its underlying mechanisms, increased sensitivity to hormonal fluctuation has been suggested to be the most plausible one (Schiller et al., 2016; Yonkers et al., 2008). Two reproductive steroid hormones, estrogen and progesterone, may play a major role (Schiller et al., 2016; Stoner et al., 2017). The levels of both hormones increase before the luteal phase and during pregnancy but rapidly decrease in the luteal phase and after parturition, and this kind of fluctuation contributes to the development of the premenstrual syndrome and postpartum depressive symptoms respectively, in those vulnerable to it (Bloch et al., 2000; Franz, 1988). It should be emphasized that hormonal fluctuation itself in patients with premenstrual syndrome or postpartum depressive symptoms is not the issue as these patients have been found to have a normal hormone level, rather, the problem is patients’ vulnerability to hormonal fluctuation (Rubinow and Schmidt, 2006). Although this may not appliable to late-onset postpartum depressive symptoms since the hormones level recovers to a steady state, this explanation seems to be most persuasive given that depression is more prevalent in women from puberty to menopause than in men of the same age, but this is reversed in childhood or after menopause (Bebbington et al., 2003; Birmaher et al., 1996; Jung et al., 2015). Meanwhile, other mechanisms have also been proposed such as inadequate vitamin D status (Jarosz and El-Sohemy, 2019; Wang et al., 2018) and cytokine effects (Stoner et al., 2017).

*4.6. Primiparity compared to multiparity*

Primiparity (Tokumitsu et al., 2020) is associated with a higher risk of postpartum depressive symptoms compared to multiparity with highly suggestive evidence, which was confirmed in all subgroup analyses except for the validated cutoff score analysis. Indeed, several reasons have been suggested as to why postpartum depressive symptoms are more prevalent in primiparity than multiparity. First, multiparity may be more experienced in adapting to stress or other adversities accompanied by pregnancy and parturition. Second, given that history of postpartum depression may be another risk factor for postpartum depressive symptoms despite its low level of evidence (class IV) (Desta et al., 2021), those who have experienced postpartum depression may endeavor not to endure it again by receiving psychological education, taking preventive measures against depression, or being reluctant to conceive again. Third, primiparous women are at an increased risk of having anxiety and sexual problems, which may eventually lead to postpartum depressive symptoms (Martínez-Galiano et al., 2019). Although the aforementioned factors may not fully account for the association and other unidentified factors may exist, this association might have major implications for healthcare professionals or national health care planners by alerting them to the necessity of paying more attention to mothers who become pregnant for the first time.

*4.7. Unintended pregnancy*

Unintended pregnancy (Qiu et al., 2020) provided highly suggestive evidence for higher risk of postpartum depressive symptoms, which was confirmed in all sensitivity analyses. In the regard that women who conceive unintentionally seem to experience psychosocial stress due to concerns after pregnancy such as interruptions in their education, career, or other life aspirations (Faisal-Cury et al., 2017; Steinberg and Rubin, 2014), stress-related neuroendocrine dysfunction and gene-stress interaction seems to be the two most plausible biological mechanisms that underlie the association between unintended pregnancy and postpartum depressive symptoms. A detailed explanation of these suggested mechanisms has already been mentioned above. Further, other behavioral mechanisms have also been suggested. First, mothers conceive without intention tend to start late and seldom complete prenatal care, which can be detrimental to maternal mental health (Karaçam et al., 2011). Second, a pregnancy that is unexpected and thus unplanned may result in adjustment stress in the mother, leading to concerns about maternal and fetal health and even conflicts regarding maintaining versus terminating the pregnancy (Faisal-Cury et al., 2017). Third, mothers with unintended pregnancies tend to smoke more and take fewer vitamins than those who have planned pregnancies, which plausibly explains their higher risk of postpartum depressive symptoms given that smoking (Chen et al., 2019) and lack of vitamin D supplementation (Sheikh et al., 2017) were significantly associated with postpartum depressive symptoms.

*4.8. Limitations*

The present study has some limitations. First, since all meta-analyses were based on observational studies, reported associations do not necessarily imply causality and we could not completely exclude potential confounders, which requires a caution in interpreting the findings. Second, most of the identified associations showed large heterogeneity. This may be due to the unstandardized way in which variables have been operationalized as well as various cutoff points for determining postpartum depression. Meanwhile, the operationalization of environmental factors may be also inconsistent across studies. Third, a large portion of meta-analyses showed “low” or “critically low” methodological quality. Majority of them did not report a protocol before conducting a review and did not provide the list of excluded articles and exclusion reason. Fourth, we could only address the associations which were synthesized by meta-analyses; that is, we may have inevitably missed some important factors. Besides, although the most current concept of “perinatal depression” includes both prenatal and postnatal maternal depression, which does not allow the discrimination between intrauterine and postnatal effects, we focused on the sole postpartum depressive symptoms. We may miss some factors related to both maternal/newborn outcomes and interventions that may directly affect and modulate the magnitude of the effects of the candidate environmental factors and biomarkers appraised herein. However, this is an intrinsic limitation since our study was based on previous meta-analyses that only focused on postpartum depression.

**5. Conclusions**

Our umbrella review identified convincing evidence indicating that antenatal anxiety and psychological violence are robustly associated with postpartum depressive symptoms, while no associated protective factors or biomarkers showed robust evidence. Since these associations cannot imply causality, further well-designed primary studies with the ICD/DSM-established operationalization of postpartum depression are needed to confirm these findings.

**Acknowledgements** There was no funding source for this study.

**Competing interests** All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi\_disclosure.pdf and declare: GSP is supported by Alicia Koplowitz Foundation and Janssen Cilaq. BS is supported by a National Institute for Health Research (NIHR) Advanced Fellowship (301206, 2021-20216). BS is a lead/co-investigator the following active grants 1) NIHR program grant: Supporting Physical and Activity through Co-production in people with Severe Mental Illness (SPACES,2021-2027); 2) TB multimorbidity with the Medical Research Council (GCRF call (2020-2022); 3) Determinants of MLTCs among young adults with mental disorders: a data-linkage study, Guy's & St Thomas' Charity (2020-2022); 4) Mechanisms underlying the role of gut-microbiota in exercise-induced changes in cognitive function in middle-age, Reta Lila Weston Trust For Medical Research (2021-2024); 5) Improving Outcomes in Mental and Physical Multi-morbidity and Developing Research Capacity (IMPACT) in South Asia, NIHR Global Research program grant (2017-2022). BS also works at King’s College London; disseminating and publishing evidence is integral to his employment (although his salary is wholly covered by the above fellowship). BS also works clinically with people that use mental health services in the National Health Service (NHS). BS has published a book on exercise and mental illness and is on the Editorial board of Ageing Research Reviews, Mental Health and Physical Activity, The Journal of Evidence Based Medicine and The Brazilian Journal of Psychiatry. BS has received honorarium for advisory work from ASICS Europe BV & Parachute BH for work unrelated to this project. The views expressed are those of the author(s) and not necessarily those of mentioned above, the NHS, the NIHR, the Department of Health and Social Care, the MRC or GSTT.

**Data sharing** All data used in this study were from publicly available articles.

**Appendix** Supplementary material on this article can be found, in the online version.

**References**

Azami, M., Badfar, G., Khalighi, Z., Qasemi, P., Shohani, M., Soleymani, A., Abbasalizadeh, S., 2019a. The association between anemia and postpartum depression: A systematic review and meta-analysis. Caspian J Intern Med 10, 115-124.

Azami, M., Badfar, G., Soleymani, A., Rahmati, S., 2019b. The association between gestational diabetes and postpartum depression: A systematic review and meta-analysis. Diabetes Res Clin Pract 149, 147-155.

Bacchus, L.J., Ranganathan, M., Watts, C., Devries, K., 2018. Recent intimate partner violence against women and health: a systematic review and meta-analysis of cohort studies. BMJ Open 8, e019995.

Balshem, H., Helfand, M., Schünemann, H.J., Oxman, A.D., Kunz, R., Brozek, J., Vist, G.E., Falck-Ytter, Y., Meerpohl, J., Norris, S., Guyatt, G.H., 2011. GRADE guidelines: 3. Rating the quality of evidence. J Clin Epidemiol 64, 401-406.

Banti, S., Mauri, M., Oppo, A., Borri, C., Rambelli, C., Ramacciotti, D., Montagnani, M.S., Camilleri, V., Cortopassi, S., Rucci, P., Cassano, G.B., 2011. From the third month of pregnancy to 1 year postpartum. Prevalence, incidence, recurrence, and new onset of depression. Results from the perinatal depression-research & screening unit study. Compr Psychiatry 52, 343-351.

Baron, J.A., 1984. Smoking and estrogen-related disease. Am J Epidemiol 119, 9-22.

Bebbington, P., Dunn, G., Jenkins, R., Lewis, G., Brugha, T., Farrell, M., Meltzer, H., 2003. The influence of age and sex on the prevalence of depressive conditions: report from the National Survey of Psychiatric Morbidity. Int Rev Psychiatry 15, 74-83.

Begni, V., Riva, M.A., Cattaneo, A., 2017. Cellular and molecular mechanisms of the brain-derived neurotrophic factor in physiological and pathological conditions. Clin Sci (Lond) 131, 123-138.

Belbasis, L., Bellou, V., Evangelou, E., Ioannidis, J.P., Tzoulaki, I., 2015. Environmental risk factors and multiple sclerosis: an umbrella review of systematic reviews and meta-analyses. Lancet Neurol 14, 263-273.

Bellou, V., Belbasis, L., Tzoulaki, I., Middleton, L.T., Ioannidis, J.P.A., Evangelou, E., 2017. Systematic evaluation of the associations between environmental risk factors and dementia: An umbrella review of systematic reviews and meta-analyses. Alzheimers Dement 13, 406-418.

Beydoun, H.A., Beydoun, M.A., Kaufman, J.S., Lo, B., Zonderman, A.B., 2012. Intimate partner violence against adult women and its association with major depressive disorder, depressive symptoms and postpartum depression: a systematic review and meta-analysis. Soc Sci Med 75, 959-975.

Birmaher, B., Ryan, N.D., Williamson, D.E., Brent, D.A., Kaufman, J., Dahl, R.E., Perel, J., Nelson, B., 1996. Childhood and adolescent depression: a review of the past 10 years. Part I. J Am Acad Child Adolesc Psychiatry 35, 1427-1439.

Black, C.N., Bot, M., Scheffer, P.G., Cuijpers, P., Penninx, B.W., 2015. Is depression associated with increased oxidative stress? A systematic review and meta-analysis. Psychoneuroendocrinology 51, 164-175.

Bloch, M., Schmidt, P.J., Danaceau, M., Murphy, J., Nieman, L., Rubinow, D.R., 2000. Effects of gonadal steroids in women with a history of postpartum depression. Am J Psychiatry 157, 924-930.

Brummelte, S., Galea, L.A., 2010. Depression during pregnancy and postpartum: contribution of stress and ovarian hormones. Prog Neuropsychopharmacol Biol Psychiatry 34, 766-776.

Brunoni, A.R., Lopes, M., Fregni, F., 2008. A systematic review and meta-analysis of clinical studies on major depression and BDNF levels: implications for the role of neuroplasticity in depression. Int J Neuropsychopharmacol 11, 1169-1180.

Cao, S., Jones, M., Tooth, L., Mishra, G.D., 2020. History of premenstrual syndrome and development of postpartum depression: A systematic review and meta-analysis. J Psychiatr Res 121, 82-90.

Chen, H.L., Cai, J.Y., Zha, M.L., Shen, W.Q., 2019. Prenatal smoking and postpartum depression: a meta-analysis. J Psychosom Obstet Gynaecol 40, 97-105.

Cochran, W.G., 1954. The combination of estimates from different experiments. Biometrics 10, 101-129.

Coelho, H.F., Murray, L., Royal-Lawson, M., Cooper, P.J., 2011. Antenatal anxiety disorder as a predictor of postnatal depression: a longitudinal study. J Affect Disord 129, 348-353.

Dachew, B.A., Ayano, G., Betts, K., Alati, R., 2021. The impact of pre-pregnancy BMI on maternal depressive and anxiety symptoms during pregnancy and the postpartum period: A systematic review and meta-analysis. J Affect Disord 281, 321-330.

Dadi, A.F., Akalu, T.Y., Baraki, A.G., Wolde, H.F., 2020. Epidemiology of postnatal depression and its associated factors in Africa: A systematic review and meta-analysis. PLoS One 15, e0231940.

de Paula Eduardo, J.A.F., de Rezende, M.G., Menezes, P.R., Del-Ben, C.M., 2019. Preterm birth as a risk factor for postpartum depression: A systematic review and meta-analysis. J Affect Disord 259, 392-403.

Desta, M., Memiah, P., Kassie, B., Ketema, D.B., Amha, H., Getaneh, T., Sintayehu, M., 2021. Postpartum depression and its association with intimate partner violence and inadequate social support in Ethiopia: a systematic review and meta-analysis. J Affect Disord 279, 737-748.

Egger, M., Davey Smith, G., Schneider, M., Minder, C., 1997. Bias in meta-analysis detected by a simple, graphical test. Bmj 315, 629-634.

Faisal-Cury, A., Menezes, P.R., Quayle, J., Matijasevich, A., 2017. Unplanned pregnancy and risk of maternal depression: secondary data analysis from a prospective pregnancy cohort. Psychol Health Med 22, 65-74.

Falah-Hassani, K., Shiri, R., Vigod, S., Dennis, C.L., 2015. Prevalence of postpartum depression among immigrant women: A systematic review and meta-analysis. J Psychiatr Res 70, 67-82.

Field, T., 2010. Postpartum depression effects on early interactions, parenting, and safety practices: a review. Infant Behav Dev 33, 1-6.

Franz, W.B., 3rd, 1988. Basic review: endocrinology of the normal menstrual cycle. Prim Care 15, 607-616.

Fusar-Poli, P., Radua, J., 2018. Ten simple rules for conducting umbrella reviews. Evid Based Ment Health 21, 95-100.

Gastaldon, C., Solmi, M., Correll, C.U., Barbui, C., Schoretsanitis, G., 2022. Risk factors of postpartum depression and depressive symptoms: umbrella review of current evidence from systematic reviews and meta-analyses of observational studies. Br J Psychiatry, 1-12.

Gavin, N.I., Gaynes, B.N., Lohr, K.N., Meltzer-Brody, S., Gartlehner, G., Swinson, T., 2005. Perinatal depression: a systematic review of prevalence and incidence. Obstet Gynecol 106, 1071-1083.

Goodman, S.H., Rouse, M.H., Connell, A.M., Broth, M.R., Hall, C.M., Heyward, D., 2011. Maternal depression and child psychopathology: a meta-analytic review. Clin Child Fam Psychol Rev 14, 1-27.

Gressier, F., Guillard, V., Cazas, O., Falissard, B., Glangeaud-Freudenthal, N.M., Sutter-Dallay, A.L., 2017. Risk factors for suicide attempt in pregnancy and the post-partum period in women with serious mental illnesses. J Psychiatr Res 84, 284-291.

Grigoriadis, S., Graves, L., Peer, M., Mamisashvili, L., Tomlinson, G., Vigod, S.N., Dennis, C.L., Steiner, M., Brown, C., Cheung, A., Dawson, H., Rector, N.A., Guenette, M., Richter, M., 2019. A systematic review and meta-analysis of the effects of antenatal anxiety on postpartum outcomes. Arch Womens Ment Health 22, 543-556.

Gump, B.B., Reihman, J., Stewart, P., Lonky, E., Darvill, T., Granger, D.A., Matthews, K.A., 2009. Trajectories of maternal depressive symptoms over her child's life span: relation to adrenocortical, cardiovascular, and emotional functioning in children. Dev Psychopathol 21, 207-225.

Higgins, J.P., Thompson, S.G., Spiegelhalter, D.J., 2009. A re-evaluation of random-effects meta-analysis. J R Stat Soc Ser A Stat Soc 172, 137-159.

Howard, L.M., Oram, S., Galley, H., Trevillion, K., Feder, G., 2013. Domestic violence and perinatal mental disorders: a systematic review and meta-analysis. PLoS Med 10, e1001452.

Hutchens, B.F., Kearney, J., 2020. Risk Factors for Postpartum Depression: An Umbrella Review. J Midwifery Womens Health 65, 96-108.

Ioannidis, J.P., 2005. Why most published research findings are false. PLoS Med 2, e124.

Ioannidis, J.P., 2008. Why most discovered true associations are inflated. Epidemiology 19, 640-648.

Ioannidis, J.P., Tarone, R., McLaughlin, J.K., 2011. The false-positive to false-negative ratio in epidemiologic studies. Epidemiology 22, 450-456.

Jarosz, A.C., El-Sohemy, A., 2019. Association between Vitamin D Status and Premenstrual Symptoms. J Acad Nutr Diet 119, 115-123.

Jones, P., Arango, C., Dragioti, E., Solmi, M., Cortese, S., Katharina, K., Murray, R., 2021. Risk and protective factors for mental disorders beyond genetics: an evidence-based atlas (in press). World Psychiatry.

Jung, S.J., Shin, A., Kang, D., 2015. Menarche age, menopause age and other reproductive factors in association with post-menopausal onset depression: Results from Health Examinees Study (HEXA). J Affect Disord 187, 127-135.

Kang, S.Y., Kim, H.B., Sunwoo, S., 2020. Association between anemia and maternal depression: A systematic review and meta-analysis. J Psychiatr Res 122, 88-96.

Karaçam, Z., Onel, K., Gerçek, E., 2011. Effects of unplanned pregnancy on maternal health in Turkey. Midwifery 27, 288-293.

Kassel, J.D., Stroud, L.R., Paronis, C.A., 2003. Smoking, stress, and negative affect: correlation, causation, and context across stages of smoking. Psychol Bull 129, 270-304.

Kim, J.H., Kim, J.Y., Lee, J., Jeong, G.H., Lee, E., Lee, S., Lee, K.H., Kronbichler, A., Stubbs, B., Solmi, M., Koyanagi, A., Hong, S.H., Dragioti, E., Jacob, L., Brunoni, A.R., Carvalho, A.F., Radua, J., Thompson, T., Smith, L., Oh, H., Yang, L., Grabovac, I., Schuch, F., Fornaro, M., Stickley, A., Rais, T.B., Salazar de Pablo, G., Shin, J.I., Fusar-Poli, P., 2020. Environmental risk factors, protective factors, and peripheral biomarkers for ADHD: an umbrella review. Lancet Psychiatry 7, 955-970.

Kim, J.Y., Son, M.J., Son, C.Y., Radua, J., Eisenhut, M., Gressier, F., Koyanagi, A., Carvalho, A.F., Stubbs, B., Solmi, M., Rais, T.B., Lee, K.H., Kronbichler, A., Dragioti, E., Shin, J.I., Fusar-Poli, P., 2019. Environmental risk factors and biomarkers for autism spectrum disorder: an umbrella review of the evidence. Lancet Psychiatry 6, 590-600.

Kountanis, J.A., Vahabzadeh, C., Bauer, S., Muzik, M., Cassidy, R., Aman, C., MacEachern, M., Bauer, M.E., 2020. Labor epidural analgesia and the risk of postpartum depression: A meta-analysis of observational studies. J Clin Anesth 61, 109658.

Lee, J., Taneja, V., Vassallo, R., 2012. Cigarette smoking and inflammation: cellular and molecular mechanisms. J Dent Res 91, 142-149.

Lin, P.Y., Chang, C.H., Chong, M.F., Chen, H., Su, K.P., 2017. Polyunsaturated Fatty Acids in Perinatal Depression: A Systematic Review and Meta-analysis. Biol Psychiatry 82, 560-569.

Mahon, P.B., Payne, J.L., MacKinnon, D.F., Mondimore, F.M., Goes, F.S., Schweizer, B., Jancic, D., Coryell, W.H., Holmans, P.A., Shi, J., Knowles, J.A., Scheftner, W.A., Weissman, M.M., Levinson, D.F., DePaulo, J.R., Jr., Zandi, P.P., Potash, J.B., 2009. Genome-wide linkage and follow-up association study of postpartum mood symptoms. Am J Psychiatry 166, 1229-1237.

Martínez-Galiano, J.M., Hernández-Martínez, A., Rodríguez-Almagro, J., Delgado-Rodríguez, M., Gómez-Salgado, J., 2019. Relationship between parity and the problems that appear in the postpartum period. Sci Rep 9, 11763.

McEvoy, J.W., Nasir, K., DeFilippis, A.P., Lima, J.A., Bluemke, D.A., Hundley, W.G., Barr, R.G., Budoff, M.J., Szklo, M., Navas-Acien, A., Polak, J.F., Blumenthal, R.S., Post, W.S., Blaha, M.J., 2015. Relationship of cigarette smoking with inflammation and subclinical vascular disease: the Multi-Ethnic Study of Atherosclerosis. Arterioscler Thromb Vasc Biol 35, 1002-1010.

Meltzer-Brody, S., 2011. New insights into perinatal depression: pathogenesis and treatment during pregnancy and postpartum. Dialogues Clin Neurosci 13, 89-100.

Minaldi, E., D'Andrea, S., Castellini, C., Martorella, A., Francavilla, F., Francavilla, S., Barbonetti, A., 2020. Thyroid autoimmunity and risk of post-partum depression: a systematic review and meta-analysis of longitudinal studies. J Endocrinol Invest 43, 271-277.

Moameri, H., Ostadghaderi, M., Khatooni, E., Doosti-Irani, A., 2019. Association of postpartum depression and cesarean section: A systematic review and meta-analysis. Clinical Epidemiology and Global Health 7, 471-480.

Molendijk, M.L., Spinhoven, P., Polak, M., Bus, B.A., Penninx, B.W., Elzinga, B.M., 2014. Serum BDNF concentrations as peripheral manifestations of depression: evidence from a systematic review and meta-analyses on 179 associations (N=9484). Mol Psychiatry 19, 791-800.

Molyneaux, E., Poston, L., Ashurst-Williams, S., Howard, L.M., 2014. Obesity and mental disorders during pregnancy and postpartum: a systematic review and meta-analysis. Obstet Gynecol 123, 857-867.

Necho, M., Abadisharew, M., Getachew, Y., 2020. A Systematic Review and Meta-analysis of Depression in Postpartum Women in a Low-income Country; Ethiopia, 2020. The Open Public Health Journal 13.

O'Hara, M.W., McCabe, J.E., 2013. Postpartum depression: current status and future directions. Annu Rev Clin Psychol 9, 379-407.

Pace, T.W., Miller, A.H., 2009. Cytokines and glucocorticoid receptor signaling. Relevance to major depression. Ann N Y Acad Sci 1179, 86-105.

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P., Moher, D., 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. Bmj 372, n71.

Papatheodorou, S.I., Tsilidis, K.K., Evangelou, E., Ioannidis, J.P., 2015. Application of credibility ceilings probes the robustness of meta-analyses of biomarkers and cancer risk. J Clin Epidemiol 68, 163-174.

Payne, J.L., Maguire, J., 2019. Pathophysiological mechanisms implicated in postpartum depression. Front Neuroendocrinol 52, 165-180.

Pearson, R.M., Evans, J., Kounali, D., Lewis, G., Heron, J., Ramchandani, P.G., O'Connor, T.G., Stein, A., 2013. Maternal depression during pregnancy and the postnatal period: risks and possible mechanisms for offspring depression at age 18 years. JAMA Psychiatry 70, 1312-1319.

Philip, N.S., Carpenter, L.L., Tyrka, A.R., Price, L.H., 2010. Nicotinic acetylcholine receptors and depression: a review of the preclinical and clinical literature. Psychopharmacology (Berl) 212, 1-12.

Qiu, X., Zhang, S., Sun, X., Li, H., Wang, D., 2020. Unintended pregnancy and postpartum depression: A meta-analysis of cohort and case-control studies. J Psychosom Res 138, 110259.

Rambelli, C., Montagnani, M.S., Oppo, A., Banti, S., Borri, C., Cortopassi, C., Ramacciotti, D., Camilleri, V., Mula, M., Cassano, G.B., Mauri, M., 2010. Panic disorder as a risk factor for post-partum depression: Results from the Perinatal Depression-Research & Screening Unit (PND-ReScU) study. J Affect Disord 122, 139-143.

Ranjbaran, M., Omani Samani, R., Almasi-Hashiani, A., Matourypour, P., Moini, A., 2017. Prevalence of premenstrual syndrome in Iran: A systematic review and meta-analysis. Int J Reprod Biomed 15, 679-686.

Robertson, E., Grace, S., Wallington, T., Stewart, D.E., 2004. Antenatal risk factors for postpartum depression: a synthesis of recent literature. Gen Hosp Psychiatry 26, 289-295.

Ruan, X., Mueck, A.O., 2015. Impact of smoking on estrogenic efficacy. Climacteric 18, 38-46.

Rubinow, D.R., Schmidt, P.J., 2006. Gonadal steroid regulation of mood: the lessons of premenstrual syndrome. Front Neuroendocrinol 27, 210-216.

Salanti, G., Ioannidis, J.P., 2009. Synthesis of observational studies should consider credibility ceilings. J Clin Epidemiol 62, 115-122.

Salimi, S., Terplan, M., Cheng, D., Chisolm, M.S., 2015. The Relationship Between Postpartum Depression and Perinatal Cigarette Smoking: An Analysis of PRAMS Data. J Subst Abuse Treat 56, 34-38.

Salmela-Aro, K., Nurmi, J.E., Saisto, T., Halmesmaki, E., 2001. Goal reconstruction and depressive symptoms during the transition to motherhood: evidence from two cross-lagged longitudinal studies. J Pers Soc Psychol 81, 1144-1159.

Schiller, C.E., Johnson, S.L., Abate, A.C., Schmidt, P.J., Rubinow, D.R., 2016. Reproductive Steroid Regulation of Mood and Behavior. Compr Physiol 6, 1135-1160.

Schiller, C.E., Meltzer-Brody, S., Rubinow, D.R., 2015. The role of reproductive hormones in postpartum depression. CNS Spectr 20, 48-59.

Segman, R.H., Goltser-Dubner, T., Weiner, I., Canetti, L., Galili-Weisstub, E., Milwidsky, A., Pablov, V., Friedman, N., Hochner-Celnikier, D., 2010. Blood mononuclear cell gene expression signature of postpartum depression. Mol Psychiatry 15, 93-100, 102.

Shea, B.J., Reeves, B.C., Wells, G., Thuku, M., Hamel, C., Moran, J., Moher, D., Tugwell, P., Welch, V., Kristjansson, E., 2017. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. bmj 358.

Sheikh, M., Hantoushzadeh, S., Shariat, M., Farahani, Z., Ebrahiminasab, O., 2017. The efficacy of early iron supplementation on postpartum depression, a randomized double-blind placebo-controlled trial. Eur J Nutr 56, 901-908.

Simonsohn, U., Nelson, L.D., Simmons, J.P., 2014a. p-Curve and Effect Size: Correcting for Publication Bias Using Only Significant Results. Perspect Psychol Sci 9, 666-681.

Simonsohn, U., Nelson, L.D., Simmons, J.P., 2014b. P-curve: a key to the file-drawer. J Exp Psychol Gen 143, 534-547.

Song, C., Li, W., Leng, J., Wang, L., Li, W., Shi, F., Liu, G., Zhou, J., Yang, X., 2019. Passive smoking and postpartum depression among Chinese women: A prospective cohort study in Tianjin, China. Women Health 59, 281-293.

Steinberg, J.R., Rubin, L.R., 2014. Psychological Aspects of Contraception, Unintended Pregnancy, and Abortion. Policy Insights Behav Brain Sci 1, 239-247.

Sterne, J.A., Davey Smith, G., 2001. Sifting the evidence-what's wrong with significance tests? Bmj 322, 226-231.

Stewart, D.E., Vigod, S., 2016. Postpartum Depression. N Engl J Med 375, 2177-2186.

Stoner, R., Camilleri, V., Calleja-Agius, J., Schembri-Wismayer, P., 2017. The cytokine-hormone axis - the link between premenstrual syndrome and postpartum depression. Gynecol Endocrinol 33, 588-592.

Tan, Q., Liu, S., Chen, D., 2021. Poor vitamin D status and the risk of maternal depression: a dose-response meta-analysis of observational studies. Public Health Nutr 24, 2161-2170.

Tokumitsu, K., Sugawara, N., Maruo, K., Suzuki, T., Shimoda, K., Yasui-Furukori, N., 2020. Prevalence of perinatal depression among Japanese women: a meta-analysis. Ann Gen Psychiatry 19, 41.

Tolossa, T., Fetensa, G., Yilma, M.T., Abadiga, M., Wakuma, B., Besho, M., Fekadu, G., Etafa, W., 2020. Postpartum depression and associated factors among postpartum women in Ethiopia: a systematic review and meta-analysis, 2020. Public Health Rev 41, 21.

Wang, J., Liu, N., Sun, W., Chen, D., Zhao, J., Zhang, W., 2018. Association between vitamin D deficiency and antepartum and postpartum depression: a systematic review and meta-analysis of longitudinal studies. Arch Gynecol Obstet 298, 1045-1059.

Yanbaeva, D.G., Dentener, M.A., Creutzberg, E.C., Wesseling, G., Wouters, E.F., 2007. Systemic effects of smoking. Chest 131, 1557-1566.

Yang, Z., Zhu, Z., Wang, C., Zhang, F., Zeng, H., 2020. Association between adverse perinatal outcomes and sleep disturbances during pregnancy: a systematic review and meta-analysis. J Matern Fetal Neonatal Med, 1-9.

Yargawa, J., Leonardi-Bee, J., 2015. Male involvement and maternal health outcomes: systematic review and meta-analysis. J Epidemiol Community Health 69, 604-612.

Ye, Z., Wang, L., Yang, T., Chen, L.Z., Wang, T., Chen, L., Zhao, L., Zhang, S., Luo, L., Qin, J., 2020. Gender of infant and risk of postpartum depression: a meta-analysis based on cohort and case-control studies. J Matern Fetal Neonatal Med, 1-10.

Yonkers, K.A., O'Brien, P.M., Eriksson, E., 2008. Premenstrual syndrome. Lancet 371, 1200-1210.

Zhang, S., Wang, L., Yang, T., Chen, L., Qiu, X., Wang, T., Chen, L., Zhao, L., Ye, Z., Zheng, Z., Qin, J., 2019. Maternal violence experiences and risk of postpartum depression: A meta-analysis of cohort studies. Eur Psychiatry 55, 90-101.

Zhao, X.H., Zhang, Z.H., 2020. Risk factors for postpartum depression: An evidence-based systematic review of systematic reviews and meta-analyses. Asian J Psychiatr 53, 102353.

Zhu, Q.Y., Huang, D.S., Lv, J.D., Guan, P., Bai, X.H., 2019. Prevalence of perinatal depression among HIV-positive women: a systematic review and meta-analysis. BMC Psychiatry 19, 330.

**Figure captions**

Figure 1. PRISMA flow chart of study selection

Figure 2. Summary estimates of environmental risk and protective factors for postpartum depressive symptoms

**Figure 1. PRISMA flow chart of study selection**

**Identification of studies via other methods**

**Identification of studies via databases and registers**

Records identified from:

Citation searching (n = 69)

Records removed *before screening*:

Duplicate records removed (n = 352)

Records marked as ineligible by automation tools (n = 0)

Records removed for other reasons (n = 0)

Records identified from:

PubMed/MEDLINE (n=407)

Embase (n=333)

Cochrane Database of Systematic Reviews (n=66)

**Identification**

Records screened

(n = 454)

Records excluded

(n = 310)

Reports not retrieved

(n = 0)

Reports not retrieved

(n = 0)

Reports sought for retrieval

(n = 69)

Reports sought for retrieval

(n = 144)

**Screening**

Reports excluded:

Did not present sufficient data for re-analysis (n=24)

Were not meta-analyses conducted with systematic methods (n=30)

Did not study risk factors, protective factors of biomarkers of postpartum depression (n=26)

Out of scope (n=27)

Another larger meta-analysis was included (n=7)

Reports assessed for eligibility

(n = 0)

Reports excluded:

Already identified via databases (n=69)

Reports assessed for eligibility

(n = 144)

Studies included in review

(n = 30)

Reports of included studies

(n = 54)

**Included**

**Figure 2. Summary estimates of environmental risk and protective factors for postpartum depressive symptoms**

테이블이(가) 표시된 사진

자동 생성된 설명

**Table 1. Level of evidence for grading levels**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Main analysis** | | | | | |
| Evidence level  Statistical analysis | Convincing  (class I) | Highly suggestive  (class II) | Suggestive  (class III) | Weak  (class IV) | Not significant  (NS) |
| Random effects p value | < 10-6 | < 10-6 | < 10-3 | < 0.05 | > 0.05 |
| Number of cases with postpartum depressive symptoms | > 1000 | > 1000 | > 1000 | x | x |
| P value of the largest study | < 0.05 | < 0.05 | x | x | x |
| Heterogeneity: *I2* | < 50% | x | x | x | x |
| Small study effects | Not detected | x | x | x | x |
| P curve analysis | Evidential value found | x | x | x | x |
| 95% prediction interval | Excludes the null | x | x | x | x |
| P value under 10% credibility ceiling | < 0.05 | x | x | x | x |
|  |  |  |  |  |  |
|  | ↓ | ↓ |  |  |  |
|  |  |  |  |  |  |
|  | **Sensitivity analyses** | | | |  |
|  | Subgroup analysis after excluding individual studies using low cut-off symptom score | | | |  |
|  | Subgroup analysis of adjusted study estimates | | | |  |
|  | Subgroup analysis of cohort studies | | | |  |
|  | Subgroup analysis of prospective cohort studies | | | |  |

**Table 2. Environmental risk/protective factors of postpartum depressive symptoms**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Exposure** | **Author, year** | **Number of cases / total population** | **Number of study estimates** | **Study design** | **Effect metrics** | **Random effects summary estimate (95% CI)** | **Random effects p-value** | ***I2*** | **95% prediction interval** | **Large heterogeneity, small study effect, loss of significance under 10% credibility ceiling, or evidential value not found under p-curve analysis** | **AMSTAR 2** | **GRADE** |
| **Convincing (class I)** | | | | | | | | | | | | |
| Antenatal anxiety | Grigoriadis 2019 | 1023 / 11758 | 7 | Cohort | OR | 2**.**49 (1**.**91 to 3**.**25) | < 0**.**000001 | 12% | 1**.**54 to 4**.**04 | None | Critically low | Moderate |
| Psychological violence | Zhang 2019 | 6734 / 59132 | 8 | Cohort | OR | 1**.**93 (1**.**54 to 2**.**42) | < 0**.**000001 | 48% | 1**.**1 to 3**.**4 | None | Critically low | Low |
| **Highly suggestive (class II)** | | | | | | | | | | | | |
| Intimate partner violence experience | Howard 2013 | 1076 / 7497 | 12 | Cohort, cross-sectional | OR | 2**.**86 (2**.**12 to 3**.**87) | < 0**.**000001 | 58% | 1**.**15 to 7**.**1 | Large heterogeneity; small study effect | High | Very low |
| Intimate partner violence during pregnancy | Beydoun 2012 | 6106 / 21339 | 17 | Cross-sectional | RR | 2**.**81 (2**.**11 to 3**.**74) | < 0**.**000001 | 87% | 0**.**86 to 9**.**21 | Large heterogeneity; small study effect | Critically low | Very low |
| Smoking during pregnancy | Chen 2019 | 2466 / 1424800 | 11 | Cohort, case-control, cross-sectional | OR | 2**.**39 (1**.**78 to 3**.**2) | < 0**.**000001 | 80% | 0**.**88 to 6**.**45 | Large heterogeneity | Critically low | Very low |
| History of premenstrual syndrome | Cao 2020 | 1400 / 8990 | 19 | Cohort, case-control, cross-sectional | OR | 2**.**2 (1**.**81 to 2**.**68) | < 0**.**000001 | 42% | 1**.**21 to 4**.**01 | Small study effect | High | Very low |
| Any type of violence experience | Zhang 2019 | 16953 / 177148 | 32 | Cohort | OR | 2**.**04 (1**.**72 to 2**.**41) | < 0**.**000001 | 94% | 0**.**88 to 4**.**73 | Large heterogeneity; small study effect | Critically low | Very low |
| Primiparity compared to multiparity | Tokumitsu 2020 | 14048 / 102006 | 39 | Cohort, case-control, cross-sectional | RR | 1**.**76 (1**.**59 to 1**.**96) | < 0**.**000001 | 52% | 1**.**2 to 2**.**58 | Large heterogeneity; small study effect | Critically low | Very low |
| Unintended pregnancy | Qiu 2020 | 5563 / 62778 | 30 | Cohort, case-control | OR | 1**.**53 (1**.**35 to 1**.**75) | < 0**.**000001 | 77% | 0**.**88 to 2**.**68 | Large heterogeneity; small study effect | Low | Very low |
| **Suggestive (class III)** | | | | | | | | | | | | |
| History of mental disorders | Dadi 2020 | 1106 / 14991 | 5 | Cohort, cross-sectional | OR | 2**.**78 (1**.**82 to 4**.**27) | 0**.**000003 | 85% | 0**.**61 to 12**.**69 | Large heterogeneity; loss of significance under 10% credibility ceiling | Moderate | Very low |
| Intimate partner violence in the past year | Bacchus 2018 | > 1000 / 9175 | 7 | Cohort | OR | 2**.**19 (1**.**39 to 3**.**45) | 0**.**00069 | 80% | 0**.**51 to 9**.**4 | Large heterogeneity; loss of significance under 10% credibility ceiling | Moderate | Very low |
| Preterm birth | de Paula Eduardo 2019 | 1042 / 8357 | 12 | Cohort, case-control, cross-sectional | OR | 2**.**14 (1**.**39 to 3**.**3) | 0**.**00052 | 66% | 0**.**54 to 8**.**45 | Large heterogeneity | Low | Low |
| Perinatal anemia | Kang 2020 | 2741 / 77838 | 6 | Cohort, case-control | RR | 2**.**13 (1**.**54 to 2**.**95) | 0**.**000005 | 44% | 0**.**92 to 4**.**91 | None | Critically low | Low |
| Domestic violence | Zhang 2019 | 2123 / 23996 | 16 | Cohort | OR | 2**.**05 (1**.**5 to 2**.**8) | 0**.**000006 | 85% | 0**.**6 to 7**.**03 | Large heterogeneity | Critically low | Very low |
| Physical violence | Zhang 2019 | 6489 / 57783 | 8 | Cohort | OR | 1**.**9 (1**.**36 to 2**.**67) | 0**.**00018 | 59% | 0**.**76 to 4**.**78 | Large heterogeneity | Critically low | Very low |
| Immigration | Falah-Hassani 2015 | 3857 / 32227 | 5 | Cohort, cross-sectional | OR | 1**.**84 (1**.**32 to 2**.**57) | 0**.**0003 | 71% | 0**.**65 to 5**.**21 | Large heterogeneity; small study effect | Low | Very low |
| Pre-pregnancy underweight | Dachew 2021 | > 1000 / 617985 | 5 | Cohort | OR | 1**.**71 (1**.**27 to 2**.**31) | 0**.**00042 | 45% | 0**.**74 to 3**.**98 | None | High | Low |
| Sexual violence | Zhang 2019 | 6196 / 56117 | 6 | Cohort | OR | 1**.**56 (1**.**28 to 1**.**9) | 0**.**000011 | 17% | 1**.**04 to 2**.**33 | None | Critically low | Low |
| Cesarean section | Moameri 2019 | 8870 / 614789 | 38 | Cohort, case-control | OR | 1**.**36 (1**.**2 to 1**.**55) | 0**.**000001 | 54% | 0**.**82 to 2**.**26 | Large heterogeneity | Critically low | Very low |
| Pre-pregnancy obesity | Molyneaux 2014 | 9085 / 90777 | 14 | Cohort, cross-sectional | OR | 1**.**34 (1**.**19 to 1**.**51) | 0**.**000003 | 48% | 1 to 1**.**8 | None | Moderate | Very low |
| Elective cesarean section | Moameri 2019 | 8589 / 609598 | 28 | Cohort, case-control | OR | 1**.**29 (1**.**12 to 1**.**49) | 0**.**00036 | 48% | 0**.**8 to 2**.**1 | Loss of significance under 10% credibility ceiling | Critically low | Low |
| **Weak (class IV)** | | | | | | | | | | | | |
| Poor social support | Tolossa 2020 | 832 / 5104 | 5 | Cross-sectional | OR | 6**.**6 (2**.**59 to 16**.**77) | 0**.**000075 | 96% | 0**.**17 to 249**.**06 | Large heterogeneity; small study effect | Critically low | Low |
| History of depression | Tolossa 2020 | 698 / 2876 | 6 | Cross-sectional | OR | 4**.**52 (2**.**69 to 7**.**59) | < 0**.**000001 | 79% | 0**.**79 to 25**.**99 | Large heterogeneity | Critically low | Very low |
| History of postpartum depression | Desta 2021 | 306 / 1361 | 3 | Cross-sectional | OR | 4**.**51 (2**.**4 to 8**.**45) | 0**.**000003 | 65% | 0 to 5009**.**21 | Large heterogeneity | Low | Low |
| Poor sleep quality | Yang 2020 | 89 / 7131 | 4 | Cross-sectional | OR | 4**.**06 (1**.**82 to 9**.**08) | 0**.**00064 | 87% | 0**.**1 to 171**.**18 | Large heterogeneity | Low | Very low |
| History of substance abuse | Desta 2021 | 306 / 1261 | 3 | Cross-sectional | OR | 3**.**78 (1**.**81 to 7**.**88) | 0**.**0004 | 82% | 0 to 26468**.**56 | Large heterogeneity | Low | Very low |
| History of infant death | Tolossa 2020 | 483 / 1909 | 5 | Cross-sectional | OR | 3**.**75 (1**.**85 to 7**.**61) | 0**.**00025 | 83% | 0**.**29 to 49**.**21 | Large heterogeneity | Critically low | Very low |
| Poor marital relationship | Necho 2020 | 948 / 5505 | 6 | Cross-sectional | OR | 3**.**38 (2**.**39 to 4**.**79) | < 0**.**000001 | 100% | 0**.**92 to 12**.**41 | Large heterogeneity | Critically low | Very low |
| History of stressful life event | Necho 2020 | 529 / 3658 | 2 | Cross-sectional | OR | 3**.**15 (1**.**71 to 5**.**79) | 0**.**00023 | 77% | NA | Large heterogeneity; loss of significance under 10% credibility ceiling; p curve analysis unavailable due to less than three significant studies | Critically low | Very low |
| Exposure to different types of intimate partner violence | Dadi 2020 | 446 / 4473 | 10 | Cohort, cross-sectional | OR | 2**.**91 (2**.**37 to 3**.**59) | < 0**.**000001 | 17% | 1**.**96 to 4**.**34 | None | Moderate | Moderate |
| Low income | Necho 2020 | 699 / 4437 | 3 | Cross-sectional | OR | 2**.**52 (1**.**74 to 3**.**63) | < 0**.**000001 | 4% | 0**.**21 to 30**.**86 | None | Critically low | Moderate |
| Adverse birth and infant health conditions | Dadi 2020 | 554 / 13560 | 5 | Cohort, cross-sectional | OR | 2**.**38 (1**.**56 to 3**.**64) | 0**.**000063 | 75% | 0**.**56 to 10**.**14 | Large heterogeneity | Moderate | Very low |
| Postpartum anemia | Azami 2019 | 1031 / 3084 | 10 | Cohort, cross-sectional | RR | 1**.**89 (1**.**25 to 2**.**84) | 0**.**0023 | 75% | 0**.**5 to 7**.**17 | Large heterogeneity; small study effect; loss of significance under 10% credibility ceiling | Critically low | Very low |
| Poor obstetric conditions | Dadi 2020 | 939 / 17095 | 8 | Cohort, cross-sectional | OR | 1**.**72 (1**.**36 to 2**.**17) | 0**.**000005 | 71% | 0**.**86 to 3**.**44 | Large heterogeneity; small study effect | Moderate | Very low |
| Gestational diabetes | Azami 2019 | 17954 / 2302311 | 14 | Cohort, case-control, cross-sectional | RR | 1**.**66 (1**.**21 to 2**.**27) | 0**.**0015 | 89% | 0**.**52 to 5**.**3 | Large heterogeneity | Critically low | Very low |
| Emergency cesarean section | Moameri 2019 | 4815 / 79442 | 10 | Cohort, case-control | OR | 1**.**63 (1**.**21 to 2**.**21) | 0**.**0014 | 68% | 0**.**66 to 4**.**04 | Large heterogeneity; small study effect | Critically low | Very low |
| Childhood abuse | Zhang 2019 | 800 / 5027 | 5 | Cohort | OR | 1**.**62 (1**.**28 to 2**.**07) | 0**.**000085 | 44% | 0**.**81 to 3**.**27 | None | Critically low | Low |
| HIV infection | Zhu 2019 | 548 / 3780 | 10 | Cohort, case-control, cross-sectional | OR | 1**.**58 (1**.**08 to 2**.**32) | 0**.**019 | 65% | 0**.**48 to 5**.**17 | Large heterogeneity; loss of significance under 10% credibility ceiling | Low | Very low |
| Anemia during pregnancy | Azami 2019 | 261 / 2785 | 8 | Cohort | RR | 1**.**24 (1 to 1**.**54) | 0**.**048 | 39% | 0**.**73 to 2**.**12 | Loss of significance under 10% credibility ceiling; p curve analysis unavailable due to less than three significant studies | Critically low | Low |
| Female infant compared to male infant | Ye 2020 | 14358 / 119281 | 29 | Cohort, case-control | OR | 1**.**15 (1**.**01 to 1**.**31) | 0**.**035 | 75% | 0**.**66 to 2 | Large heterogeneity; small study effect; loss of significance under 10% credibility ceiling | Critically low | Very low |
| Pre-pregnancy overweight | Dachew 2021 | 983 / 619568 | 6 | Cohort | OR | 1**.**14 (1 to 1**.**3) | 0**.**043 | 27% | 0**.**85 to 1**.**53 | Loss of significance under 10% credibility ceiling; p curve analysis unavailable due to less than three significant studies | High | Low |
| Active husband participation in maternal healthcare/services during pregnancy | Yargawa 2015 | 156 / 875 | 2 | Cohort, cross-sectional | OR | 0**.**36 (0**.**2 to 0**.**68) | 0**.**0014 | 48% | NA | Loss of significance under 10% credibility ceiling; p curve analysis unavailable due to less than three significant studies | Low | Low |
| Active husband participation in maternal healthcare/services postpartum | Yargawa 2015 | 484 / 2149 | 5 | Cohort, case-control, cross-sectional | OR | 0**.**34 (0**.**19 to 0**.**62) | 0**.**00038 | 57% | 0**.**06 to 2 | Large heterogeneity | Low | Low |
| **Not significant (NS)** | | | | | | | | | | | | |
| Family history of mental illness | Necho 2020 | 299 / 1198 | 2 | Cross-sectional | OR | 1**.**93 (0**.**66 to 5**.**62) | 0**.**23 | 75% | NA | Large heterogeneity | Critically low | Very low |
| Labor epidural analgesia | Kountanis 2020 | 609 / 5322 | 10 | Cohort, case-control | OR | 1**.**03 (0**.**71 to 1**.**52) | 0**.**86 | 79% | 0**.**3 to 3**.**55 | Large heterogeneity | Critically low | Very low |
| All statistical tests are two-sided. Abbreviations: AMSTAR 2, A Measurement Tool to Assess Systematic Reviews 2; CI, confidence interval; GRADE, Grading of Recommendations, Assessment, Development and Evaluations; HIV, human immunodeficiency virus; NA, not available; OR, odds ratio; RR, relative risk | | | | | | | | | | | | |

**Supplementary material**

Environmental risk factors, protective factors, and biomarkers for postpartum depressive symptoms: an umbrella review

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The list of excluded meta-analyses by full text screening with exclusion reason

References of the excluded meta-analyses by full text screening

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**PRISMA checklist**

| Section and Topic | Item # | Checklist item | Location where item is reported |
| --- | --- | --- | --- |
| TITLE | | |  |
| Title | 1 | Identify the report as a systematic review. | Manuscript p 1 |
| ABSTRACT | | |  |
| Abstract | 2 | See the PRISMA 2020 for Abstract checklist. | Supplementary material p 7 |
| INTRODUCTION | | |  |
| Rationale | 3 | Describe the rationale for the review in the context of existing knowledge. | Manuscript p 4 |
| Objectives | 4 | Provide an explicit statement of the objective(s) or question(s) the review addresses. | Manuscript p 4 |
| METHODS | | |  |
| Eligibility criteria | 5 | Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses. | Manuscript p 5 |
| Information sources | 6 | Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted. | Manuscript p 5, Figure 1 |
| Search strategy | 7 | Present the full search strategies for all databases, registers and websites, including any filters and limits used. | Manuscript p 5,  Supplementary material p 8 |
| Selection process | 8 | Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process. | Manuscript p 5 |
| Data collection process | 9 | Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process. | Manuscript p 5 |
| Data items | 10a | List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect. | Manuscript p 5-6 |
| 10b | List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information. | Manuscript p 5-6 |
| Study risk of bias assessment | 11 | Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process. | Manuscript p 6 |
| Effect measures | 12 | Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results. | Manuscript p 6 |
| Synthesis methods | 13a | Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)). | Manuscript p 6 |
| 13b | Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions. | Manuscript p 6 |
| 13c | Describe any methods used to tabulate or visually display results of individual studies and syntheses. | Manuscript p 6 |
| 13d | Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used. | Manuscript p 6 |
| 13e | Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression). | Manuscript p 6-7 |
| 13f | Describe any sensitivity analyses conducted to assess robustness of the synthesized results. | Manuscript p 6-7 |
| Reporting bias assessment | 14 | Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases). | Manuscript p 6-7 |
| Certainty assessment | 15 | Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome. | Manuscript p 6 |
| RESULTS | | |  |
| Study selection | 16a | Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram. | Manuscript p 7, Figure 1 |
| 16b | Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded. | Supplementary material pp 13-18 |
| Study characteristics | 17 | Cite each included study and present its characteristics. | Table 2,  Manuscript p 7, Supplementary material pp 11-12 |
| Risk of bias in studies | 18 | Present assessments of risk of bias for each included study. | Table 2,  Manuscript p 8 |
| Results of individual studies | 19 | For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots. | Table 2, S1-3, Figure 2, S1-54 |
| Results of syntheses | 20a | For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies. | Table 2, S1-3, Figure 2, S1-54 |
| 20b | Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect. | Table 2, S1-3, Figure 2, S1-54 |
| 20c | Present results of all investigations of possible causes of heterogeneity among study results. | Manuscript pp 8-9, Table S2 |
| 20d | Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results. | Manuscript pp 8-9, Table S2 |
| Reporting biases | 21 | Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed. | Manuscript pp 7-8, Table S2 |
| Certainty of evidence | 22 | Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed. | Manuscript pp 7-8, Table 2, Figure 2 |
| DISCUSSION | | |  |
| Discussion | 23a | Provide a general interpretation of the results in the context of other evidence. | Manuscript p 9 |
| 23b | Discuss any limitations of the evidence included in the review. | Manuscript p 13 |
| 23c | Discuss any limitations of the review processes used. | Manuscript p 13 |
| 23d | Discuss implications of the results for practice, policy, and future research. | Manuscript pp 9-13 |
| OTHER INFORMATION | | |  |
| Registration and protocol | 24a | Provide registration information for the review, including register name and registration number, or state that the review was not registered. | Manuscript p 5 |
| 24b | Indicate where the review protocol can be accessed, or state that a protocol was not prepared. | Manuscript p 5 |
| 24c | Describe and explain any amendments to information provided at registration or in the protocol. | No amendments to information |
| Support | 25 | Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review. | Manuscript p 14 |
| Competing interests | 26 | Declare any competing interests of review authors. | Manuscript p 14 |
| Availability of data, code and other materials | 27 | Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review. | Manuscript p 14 |

*From:*  Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

**PRISMA Abstract checklist**

Some checklist items cannot be included in the abstract due to the word count restriction. (<170 words)

| Section and Topic | Item # | Checklist item | Reported (Yes/No) |
| --- | --- | --- | --- |
| TITLE | | |  |
| Title | 1 | Identify the report as a systematic review. | Yes |
| BACKGROUND | | |  |
| Objectives | 2 | Provide an explicit statement of the main objective(s) or question(s) the review addresses. | Yes |
| METHODS | | |  |
| Eligibility criteria | 3 | Specify the inclusion and exclusion criteria for the review. | Yes |
| Information sources | 4 | Specify the information sources (e.g. databases, registers) used to identify studies and the date when each was last searched. | Yes |
| Risk of bias | 5 | Specify the methods used to assess risk of bias in the included studies. | No |
| Synthesis of results | 6 | Specify the methods used to present and synthesise results. | No |
| RESULTS | | |  |
| Included studies | 7 | Give the total number of included studies and participants and summarise relevant characteristics of studies. | Yes |
| Synthesis of results | 8 | Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e. which group is favoured). | Yes |
| DISCUSSION | | |  |
| Limitations of evidence | 9 | Provide a brief summary of the limitations of the evidence included in the review (e.g. study risk of bias, inconsistency and imprecision). | No |
| Interpretation | 10 | Provide a general interpretation of the results and important implications. | No |
| OTHER | | |  |
| Funding | 11 | Specify the primary source of funding for the review. | No |
| Registration | 12 | Provide the register name and registration number. | Yes |

*From:*  Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

**Full search strategy (The last search done in Jan 12, 2021)**

|  |
| --- |
| PubMed |
| (Postpartum[Tiab] OR postnatal[Tiab] OR puerperal[Tiab] OR perinatal[Tiab]) AND (depression[Tiab] OR depress\*[Tiab] OR "depression, postpartum"[MeSH Terms]) AND (meta-analy\*[all fields] OR meta-analysis[publication type] OR "Meta-Analysis as Topic"[Mesh])  407 articles were found. |
| Embase |
| (Postpartum OR postnatal OR puerperal OR perinatal) AND (depression OR depress\* OR "depression, postpartum") AND meta-analy\* NOT ('conference abstract':it OR 'conference paper':it OR 'conference review':it OR editorial:it OR note:it OR letter:it OR 'short survey':it)  333 articles were found. |
| Cochrane Database of Systematic Reviews |
| (Postpartum OR postnatal OR puerperal OR perinatal) AND (depression OR depress\* OR "depression, postpartum")  66 articles were found. |

**Definitions of environmental risk/protective factor and biomarker**

|  |
| --- |
| Environmental risk/protective factor |
| A risk factor is any attribute, characteristic or exposure of an individual that increases the likelihood of developing a disease or injury.  \* Additionally, in our review, protective factors were defined as any attribute, characteristic, or exposure of an individual that decreases the likelihood of developing a disease or injury. |
| Biomarker |
| A biomarker is any substance, structure, or process that can be measured in the body or its products and influence or predict the incidence of outcome or disease. |

**Validated diagnostic criteria and cut-off values used to diagnose postpartum depressive symptoms**

|  |  |
| --- | --- |
| Validated diagnostic criteria | Cut-off values (≥n) |
| BDI-IA1 | 10 |
| BDI-II1 | 14 |
| BDI-FS1 | 4 |
| BDI-SF2 | 10 |
| BSI3 | 0.76 |
| CES-D1 | 16 |
| CES-D 84 | 9 |
| EPDS5 | 10 |
| HADS6 | 7 |
| HAM-D7 | 9 |
| PDSS8 | 60 |
| PHQ-29 | 2 |
| PHQ-810 | 10 |
| PHQ-911 | 10 |
| SCL-812 | 1 |
| SRQ-2013 | 7 |

Abbreviations: BDI- II, Beck Depression Inventory–II; BDI-FS, Beck Depression Inventory-Fast Screen; BDI-IA, Amended Beck Depression Inventory; BSI, Brief Symptom Inventory; CES-D, Center for Epidemiologic Studies Depression; CES-D 8, 8-item short version of the Center for Epidemiologic Studies-Depression Scale; EPDS, Edinburgh Postnatal Depression Scale; HADS, Hospital Anxiety and Depression Scale; HAM-D, Hamilton Depression Rating Scale; PDSS, Postpartum Depression Screening Scale; PHQ-2, Patient Health Questionnaire-2 ; PHQ-8, Patient Health Questionnaire-8 ; PHQ-9, Patient Health Questionnaire-9 ; SCL-8, (Hopkins) Symptom Checklist-8; SRQ-20, WHO Self-Reporting Questionnaire 20

1. Smarr KL, Keefer AL. Measures of Depression and Depressive Symptoms. *Arthritis Care Res (Hoboken)* 2020; 72 Suppl 10: 608-29.

2. Furlanetto LM, Mendlowicz MV, Bueno JR. The validity of the Beck Depression Inventory-Short Form as a screening and diagnostic instrument for moderate and severe depression in medical inpatients. *Journal of affective disorders* 2005; 86(1): 87-91.

3. De Beurs E, Zitman F. The Brief Symptom Inventory (BSI): reliability and validity of a practical alternative to SCL-90. *MGV* 2006; 61: 120-41.

4. Briggs R, Carey D, O’Halloran A, Kenny R, Kennelly S. Validation of the 8-item Centre for Epidemiological Studies Depression Scale in a cohort of community-dwelling older people: data from The Irish Longitudinal Study on Ageing (TILDA). *European Geriatric Medicine* 2018; 9(1): 121-6.

5. Wisner KL, Sit DK, McShea MC, et al. Onset timing, thoughts of self-harm, and diagnoses in postpartum women with screen-positive depression findings. *JAMA Psychiatry* 2013; 70(5): 490-8.

6. Wu Y, Levis B, Sun Y, et al. Accuracy of the Hospital Anxiety and Depression Scale Depression subscale (HADS-D) to screen for major depression: systematic review and individual participant data meta-analysis. *Bmj* 2021; 373: n972.

7. Zimmerman M, Martinez JH, Young D, Chelminski I, Dalrymple K. Severity classification on the Hamilton Depression Rating Scale. *J Affect Disord* 2013; 150(2): 384-8.

8. Beck CT, Gable RK. Further validation of the Postpartum Depression Screening Scale. *Nurs Res* 2001; 50(3): 155-64.

9. Manea L, Gilbody S, Hewitt C, et al. Identifying depression with the PHQ-2: A diagnostic meta-analysis. *J Affect Disord* 2016; 203: 382-95.

10. Kroenke K, Strine TW, Spitzer RL, Williams JB, Berry JT, Mokdad AH. The PHQ-8 as a measure of current depression in the general population. *J Affect Disord* 2009; 114(1-3): 163-73.

11. Levis B, Benedetti A, Thombs BD. Accuracy of Patient Health Questionnaire-9 (PHQ-9) for screening to detect major depression: individual participant data meta-analysis. *Bmj* 2019; 365: l1476.

12. Fink P, Ørnbøl E, Hansen MS, Søndergaard L, De Jonge P. Detecting mental disorders in general hospitals by the SCL-8 scale. *Journal of Psychosomatic Research* 2004; 56(3): 371-5.

13. van der Westhuizen C, Wyatt G, Williams JK, Stein DJ, Sorsdahl K. Validation of the Self Reporting Questionnaire 20-Item (SRQ-20) for Use in a Low- and Middle-Income Country Emergency Centre Setting. *Int J Ment Health Addict* 2016; 14(1): 37-48.

**References of the included meta-analyses**

1. Azami M, Badfar G, Khalighi Z, Qasemi P, Shohani M, Soleymani A, et al. The association between anemia and postpartum depression: A systematic review and meta-analysis. Caspian J Intern Med. 2019;10(2):115-24.

2. Azami M, Badfar G, Soleymani A, Rahmati S. The association between gestational diabetes and postpartum depression: A systematic review and meta-analysis. Diabetes Res Clin Pract. 2019;149:147-55.

3. Bacchus LJ, Ranganathan M, Watts C, Devries K. Recent intimate partner violence against women and health: a systematic review and meta-analysis of cohort studies. BMJ Open. 2018;8(7):e019995.

4. Beydoun HA, Beydoun MA, Kaufman JS, Lo B, Zonderman AB. Intimate partner violence against adult women and its association with major depressive disorder, depressive symptoms and postpartum depression: a systematic review and meta-analysis. Soc Sci Med. 2012;75(6):959-75.

5. Cao S, Jones M, Tooth L, Mishra GD. History of premenstrual syndrome and development of postpartum depression: A systematic review and meta-analysis. J Psychiatr Res. 2020;121:82-90.

6. Chen HL, Cai JY, Zha ML, Shen WQ. Prenatal smoking and postpartum depression: a meta-analysis. J Psychosom Obstet Gynaecol. 2019;40(2):97-105.

7. Dachew BA, Ayano G, Betts K, Alati R. The impact of pre-pregnancy BMI on maternal depressive and anxiety symptoms during pregnancy and the postpartum period: A systematic review and meta-analysis. J Affect Disord. 2021;281:321-30.

8. Dadi AF, Akalu TY, Baraki AG, Wolde HF. Epidemiology of postnatal depression and its associated factors in Africa: A systematic review and meta-analysis. PLoS One. 2020;15(4):e0231940.

9. de Paula Eduardo JAF, de Rezende MG, Menezes PR, Del-Ben CM. Preterm birth as a risk factor for postpartum depression: A systematic review and meta-analysis. J Affect Disord. 2019;259:392-403.

10. Desta M, Memiah P, Kassie B, Ketema DB, Amha H, Getaneh T, et al. Postpartum depression and its association with intimate partner violence and inadequate social support in Ethiopia: a systematic review and meta-analysis. J Affect Disord. 2021;279:737-48.

11. Falah-Hassani K, Shiri R, Vigod S, Dennis CL. Prevalence of postpartum depression among immigrant women: A systematic review and meta-analysis. J Psychiatr Res. 2015;70:67-82.

12. Grigoriadis S, Graves L, Peer M, Mamisashvili L, Tomlinson G, Vigod SN, et al. A systematic review and meta-analysis of the effects of antenatal anxiety on postpartum outcomes. Arch Womens Ment Health. 2019;22(5):543-56.

13. Howard LM, Oram S, Galley H, Trevillion K, Feder G. Domestic violence and perinatal mental disorders: a systematic review and meta-analysis. PLoS Med. 2013;10(5):e1001452.

14. Kang SY, Kim HB, Sunwoo S. Association between anemia and maternal depression: A systematic review and meta-analysis. J Psychiatr Res. 2020;122:88-96.

15. Kountanis JA, Vahabzadeh C, Bauer S, Muzik M, Cassidy R, Aman C, et al. Labor epidural analgesia and the risk of postpartum depression: A meta-analysis of observational studies. J Clin Anesth. 2020;61:109658.

16. Lin PY, Chang CH, Chong MF, Chen H, Su KP. Polyunsaturated Fatty Acids in Perinatal Depression: A Systematic Review and Meta-analysis. Biol Psychiatry. 2017;82(8):560-9.

17. Minaldi E, D'Andrea S, Castellini C, Martorella A, Francavilla F, Francavilla S, et al. Thyroid autoimmunity and risk of post-partum depression: a systematic review and meta-analysis of longitudinal studies. J Endocrinol Invest. 2020;43(3):271-7.

18. Moameri H, Ostadghaderi M, Khatooni E, Doosti-Irani A. Association of postpartum depression and cesarean section: A systematic review and meta-analysis. Clinical Epidemiology and Global Health. 2019;7(3):471-80.

19. Tokumitsu K, Sugawara N, Maruo K, Suzuki T, Shimoda K, Yasui-Furukori N. Prevalence of perinatal depression among Japanese women: a meta-analysis. Ann Gen Psychiatry. 2020;19:41.

20. Tolossa T, Fetensa G, Yilma MT, Abadiga M, Wakuma B, Besho M, et al. Postpartum depression and associated factors among postpartum women in Ethiopia: a systematic review and meta-analysis, 2020. Public Health Rev. 2020;41:21.

21. Wang J, Liu N, Sun W, Chen D, Zhao J, Zhang W. Association between vitamin D deficiency and antepartum and postpartum depression: a systematic review and meta-analysis of longitudinal studies. Arch Gynecol Obstet. 2018;298(6):1045-59.

22. Yang Z, Zhu Z, Wang C, Zhang F, Zeng H. Association between adverse perinatal outcomes and sleep disturbances during pregnancy: a systematic review and meta-analysis. J Matern Fetal Neonatal Med. 2020:1-9.

23. Yargawa J, Leonardi-Bee J. Male involvement and maternal health outcomes: systematic review and meta-analysis. J Epidemiol Community Health. 2015;69(6):604-12.

24. Ye Z, Wang L, Yang T, Chen LZ, Wang T, Chen L, et al. Gender of infant and risk of postpartum depression: a meta-analysis based on cohort and case-control studies. J Matern Fetal Neonatal Med. 2020:1-10.

25. Zhang S, Wang L, Yang T, Chen L, Qiu X, Wang T, et al. Maternal violence experiences and risk of postpartum depression: A meta-analysis of cohort studies. Eur Psychiatry. 2019;55:90-101.

26. Zhu QY, Huang DS, Lv JD, Guan P, Bai XH. Prevalence of perinatal depression among HIV-positive women: a systematic review and meta-analysis. BMC Psychiatry. 2019;19(1):330.

27. Molyneaux E, Poston L, Ashurst-Williams S, Howard LM. Obesity and mental disorders during pregnancy and postpartum: a systematic review and meta-analysis. Obstet Gynecol. 2014;123(4):857-67.

28. Necho M, Abadisharew M, Getachew Y. A Systematic Review and Meta-analysis of Depression in Postpartum Women in a Low-income Country; Ethiopia, 2020. The Open Public Health Journal. 2020;13(1).

29. Qiu X, Zhang S, Sun X, Li H, Wang D. Unintended pregnancy and postpartum depression: A meta-analysis of cohort and case-control studies. J Psychosom Res. 2020;138:110259.

30. Tan Q, Liu S, Chen D. Poor vitamin D status and the risk of maternal depression: a dose-response meta-analysis of observational studies. Public Health Nutr. 2021;24(8):2161-70.

**The list of excluded meta-analyses by full text screening with exclusion reason**

|  |  |
| --- | --- |
| Abajobir, et al. 20161 | Another larger meta-analysis of same topic was included |
| Almeida, et al. 20202 | Another larger meta-analysis of same topic was included |
| Arafa, et al. 20193 | Another larger meta-analysis of same topic was included |
| Sun, et al. 20204 | Another larger meta-analysis of same topic was included |
| Wilson, et al. 20205 | Another larger meta-analysis of same topic was included |
| Wu, et al. 20126 | Another larger meta-analysis of same topic was included |
| Xu, et al. 20177 | Another larger meta-analysis of same topic was included |
| Bahadoran, et al. 20148 | Did not present sufficient data for re-analysis |
| Beck, et al. 19969 | Did not present sufficient data for re-analysis |
| Beck, et al. 200110 | Did not present sufficient data for re-analysis |
| Caropreso, et al. 202011 | Did not present sufficient data for re-analysis |
| Cluxton-Keller, et al. 201812 | Did not present sufficient data for re-analysis |
| Edwards, et al. 202113 | Did not present sufficient data for re-analysis |
| Emamian, et al. 201914 | Did not present sufficient data for re-analysis |
| Fellmeth, et al. 201715 | Did not present sufficient data for re-analysis |
| Gong, et al. 201716 | Did not present sufficient data for re-analysis |
| Hessami, et al. 202017 | Did not present sufficient data for re-analysis |
| Molyneaux, et al. 201418 | Did not present sufficient data for re-analysis |
| Mu, et al. 201919 | Did not present sufficient data for re-analysis |
| Nakamura, et al. 201920 | Did not present sufficient data for re-analysis |
| O'Hara, et al. 199621 | Did not present sufficient data for re-analysis |
| Özcan, et al. 201722 | Did not present sufficient data for re-analysis |
| Paulson, et al. 201023 | Did not present sufficient data for re-analysis |
| Pilkington, et al. 201524 | Did not present sufficient data for re-analysis |
| Pritchett, et al. 201725 | Did not present sufficient data for re-analysis |
| Racine, et al. 202126 | Did not present sufficient data for re-analysis |
| Suradom, et al. 202027 | Did not present sufficient data for re-analysis |
| Thiel, et al. 202028 | Did not present sufficient data for re-analysis |
| Veenendaal, et al. 202029 | Did not present sufficient data for re-analysis |
| Veisani, et al. 201330 | Did not present sufficient data for re-analysis |
| Wilson, et al. 201931 | Did not present sufficient data for re-analysis |
| Carter, et al. 201932 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Dennis, et al. 200433 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Dennis, et al. 200534 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Dhillon, et al. 201735 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Dodd, et al. 201536 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Dol, et al. 202037 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Geller, et al. 201738 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Hall, et al. 202039 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Huang, et al. 202040 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Lavender, et al. 201341 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Lin, et al. 201842 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Littleton, et al. 200743 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Meyrel, et al. 201844 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| O'Connor, et al. 201945 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Poyatos-León, et al. 201746 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Shorey, et al. 201847 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Sockol, et al. 201348 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Sockol, et al. 201549 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Sockol, et al. 201850 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Stuart, et al. 200351 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Taylor, et al. 201652 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Tong, et al. 201953 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Warsiti, et al. 202054 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Wojcieszek, et al. 201855 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Woody, et al. 201756 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Yonemoto, et al. 201757 | Did not study risk factors, protective factors, or biomarkers of postpartum depression |
| Anderson, et al. 201758 | Out of scope |
| Azam, et al. 201459 | Out of scope |
| Beck, et al. 200260 | Out of scope |
| Brown, et al. 201861 | Out of scope |
| Chen, et al. 201962 | Out of scope |
| Chowdhury, et al. 201563 | Out of scope |
| Cuijpers, et al. 200564 | Out of scope |
| Dachew, et al. 202065 | Out of scope |
| Dale, et al. 200866 | Out of scope |
| Davenport, et al. 201867 | Out of scope |
| Dipietro, et al. 201968 | Out of scope |
| González-Mesa, et al. 201969 | Out of scope |
| Hofmeyr, et al. 201570 | Out of scope |
| Hösli, et al. 200771 | Out of scope |
| Hutchens, et al. 202072 | Out of scope |
| Luo, et al. 200773 | Out of scope |
| Mersha, et al. 201874 | Out of scope |
| O'Connor, et al. 201675 | Out of scope |
| O'Connor, et al. 201976 | Out of scope |
| Owais, et al. 202077 | Out of scope |
| Park, et al. 202078 | Out of scope |
| Robertson, et al. 200479 | Out of scope |
| Suzuki, et al. 201980 | Out of scope |
| Upadhyay, et al. 201781 | Out of scope |
| Yan, et al. 202082 | Out of scope |
| Yonemoto, et al. 201383 | Out of scope |
| Zhao, et al. 202084 | Out of scope |
| Austin, et al. 200885 | Were not meta-analyses conducted with systematic methods |
| Ayano, et al. 201986 | Were not meta-analyses conducted with systematic methods |
| Bastos, et al. 201587 | Were not meta-analyses conducted with systematic methods |
| Chen, et al. 201988 | Were not meta-analyses conducted with systematic methods |
| Dencker, et al. 201989 | Were not meta-analyses conducted with systematic methods |
| Dennis, et al. 200890 | Were not meta-analyses conducted with systematic methods |
| Dennis, et al. 200891 | Were not meta-analyses conducted with systematic methods |
| Duko, et al. 202092 | Were not meta-analyses conducted with systematic methods |
| Field, et al. 201693 | Were not meta-analyses conducted with systematic methods |
| Gilinsky, et al. 201594 | Were not meta-analyses conducted with systematic methods |
| Giuseppe, et al. 201495 | Were not meta-analyses conducted with systematic methods |
| Gould, et al. 201796 | Were not meta-analyses conducted with systematic methods |
| Hahn-Holbrook, et al. 201797 | Were not meta-analyses conducted with systematic methods |
| Ip, et al. 200798 | Were not meta-analyses conducted with systematic methods |
| Karaçam, et al. 201899 | Were not meta-analyses conducted with systematic methods |
| Middleton, et al. 2018100 | Were not meta-analyses conducted with systematic methods |
| Miller, et al. 2013101 | Were not meta-analyses conducted with systematic methods |
| Molyneaux, et al. 2018102 | Were not meta-analyses conducted with systematic methods |
| Nilaweera, et al. 2014103 | Were not meta-analyses conducted with systematic methods |
| Øverland, et al. 2019104 | Were not meta-analyses conducted with systematic methods |
| Psarraki, et al. 2020105 | Were not meta-analyses conducted with systematic methods |
| Ribamar, et al. 2020106 | Were not meta-analyses conducted with systematic methods |
| Rollè, et al. 2020107 | Were not meta-analyses conducted with systematic methods |
| Ross, et al. 2006108 | Were not meta-analyses conducted with systematic methods |
| Saccone, et al. 2016109 | Were not meta-analyses conducted with systematic methods |
| Scope, et al. 2017110 | Were not meta-analyses conducted with systematic methods |
| Scott, et al. 1999111 | Were not meta-analyses conducted with systematic methods |
| Tobin, et al. 2018112 | Were not meta-analyses conducted with systematic methods |
| Villegas, et al. 2011113 | Were not meta-analyses conducted with systematic methods |
| Wilson, et al. 1996114 | Were not meta-analyses conducted with systematic methods |

**References of the excluded meta-analyses by full text screening**

1. Abajobir AA, Maravilla JC, Alati R, Najman JM. A systematic review and meta-analysis of the association between unintended pregnancy and perinatal depression. J Affect Disord 2016; 192: 56-63.

2. Almeida M, Kosman KA, Kendall MC, De Oliveira GS. The association between labor epidural analgesia and postpartum depression: a systematic review and meta-analysis. BMC Womens Health 2020; 20(1): 99.

3. Arafa A, Dong JY. Gestational diabetes and risk of postpartum depressive symptoms: A meta-analysis of cohort studies. J Affect Disord 2019; 253: 312-6.

4. Sun L, Wang S, Li XQ. Association between mode of delivery and postpartum depression: A systematic review and network meta-analysis. Aust N Z J Psychiatry 2020: 4867420954284.

5. Wilson CA, Newham J, Rankin J, et al. Is there an increased risk of perinatal mental disorder in women with gestational diabetes? A systematic review and meta-analysis. Diabet Med 2020; 37(4): 602-22.

6. Wu Q, Chen HL, Xu XJ. Violence as a risk factor for postpartum depression in mothers: a meta-analysis. Arch Womens Ment Health 2012; 15(2): 107-14.

7. Xu H, Ding Y, Ma Y, Xin X, Zhang D. Cesarean section and risk of postpartum depression: A meta-analysis. J Psychosom Res 2017; 97: 118-26.

8. Bahadoran P, Oreizi HR, Safari S. Meta-analysis of the role of delivery mode in postpartum depression (Iran 1997-2011). J Educ Health Promot 2014; 3: 118.

9. Beck CT. A meta-analysis of predictors of postpartum depression. Nurs Res 1996; 45(5): 297-303.

10. Beck CT. Predictors of postpartum depression: an update. Nurs Res 2001; 50(5): 275-85.

11. Caropreso L, de Azevedo Cardoso T, Eltayebani M, Frey BN. Preeclampsia as a risk factor for postpartum depression and psychosis: a systematic review and meta-analysis. Arch Womens Ment Health 2020; 23(4): 493-505.

12. Cluxton-Keller F, Bruce ML. Clinical effectiveness of family therapeutic interventions in the prevention and treatment of perinatal depression: A systematic review and meta-analysis. PLoS One 2018; 13(6): e0198730.

13. Edwards LM, Le HN, Garnier-Villarreal M. A Systematic Review and Meta-Analysis of Risk Factors for Postpartum Depression Among Latinas. Matern Child Health J 2021; 25(4): 554-64.

14. Emamian F, Khazaie H, Okun ML, Tahmasian M, Sepehry AA. Link between insomnia and perinatal depressive symptoms: A meta-analysis. J Sleep Res 2019; 28(6): e12858.

15. Fellmeth G, Fazel M, Plugge E. Migration and perinatal mental health in women from low- and middle-income countries: a systematic review and meta-analysis. Bjog 2017; 124(5): 742-52.

16. Gong S, Fan Y, Li L, Meng F. Influence of doula delivery on postpartum depression in puerperae: A meta-analysis. Chinese Journal of Evidence-Based Medicine 2017; 17: 1037-42.

17. Hessami K, Romanelli C, Chiurazzi M, Cozzolino M. COVID-19 pandemic and maternal mental health: a systematic review and meta-analysis. J Matern Fetal Neonatal Med 2020: 1-8.

18. Molyneaux E, Poston L, Ashurst-Williams S, Howard LM. Pre-pregnancy obesity and mental disorders during pregnancy and postpartum: A systematic review and meta-analysis. Pregnancy Hypertens 2014; 4(3): 236.

19. Mu TY, Li YH, Pan HF, et al. Postpartum depressive mood (PDM) among Chinese women: a meta-analysis. Arch Womens Ment Health 2019; 22(2): 279-87.

20. Nakamura A, van der Waerden J, Melchior M, Bolze C, El-Khoury F, Pryor L. Physical activity during pregnancy and postpartum depression: Systematic review and meta-analysis. J Affect Disord 2019; 246: 29-41.

21. O'Hara MW, Swain AM. Rates and risk of postpartum depression-A meta-analysis. International Review of Psychiatry 1996; 8(1): 37-54.

22. Özcan NK, Boyacıoğlu NE, Dinç H. Postpartum Depression Prevalence and Risk Factors in Turkey: A Systematic Review and Meta-Analysis. Arch Psychiatr Nurs 2017; 31(4): 420-8.

23. Paulson JF, Bazemore SD. Prenatal and postpartum depression in fathers and its association with maternal depression: a meta-analysis. Jama 2010; 303(19): 1961-9.

24. Pilkington PD, Milne LC, Cairns KE, Lewis J, Whelan TA. Modifiable partner factors associated with perinatal depression and anxiety: a systematic review and meta-analysis. J Affect Disord 2015; 178: 165-80.

25. Pritchett RV, Daley AJ, Jolly K. Does aerobic exercise reduce postpartum depressive symptoms? a systematic review and meta-analysis. Br J Gen Pract 2017; 67(663): e684-e91.

26. Racine N, Devereaux C, Cooke JE, Eirich R, Zhu J, Madigan S. Adverse childhood experiences and maternal anxiety and depression: a meta-analysis. BMC Psychiatry 2021; 21(1): 28.

27. Suradom C, Suttajit S, Oon-Arom A, Maneeton B, Srisurapanont M. Omega-3 polyunsaturated fatty acid (n-3 PUFA) supplementation for prevention and treatment of perinatal depression: a systematic review and meta-analysis of randomized-controlled trials. Nord J Psychiatry 2021; 75(4): 239-46.

28. Thiel F, Pittelkow MM, Wittchen HU, Garthus-Niegel S. The Relationship Between Paternal and Maternal Depression During the Perinatal Period: A Systematic Review and Meta-Analysis. Front Psychiatry 2020; 11: 563287.

29. van Veenendaal NR, van Kempen A, Franck LS, et al. Hospitalising preterm infants in single family rooms versus open bay units: A systematic review and meta-analysis of impact on parents. EClinicalMedicine 2020; 23: 100388.

30. Veisani Y, Delpisheh A, Sayehmiri K, Rezaeian S. Trends of postpartum depression in iran: a systematic review and meta-analysis. Depress Res Treat 2013; 2013: 291029.

31. Wilson N, Lee JJ, Bei B. Postpartum fatigue and depression: A systematic review and meta-analysis. J Affect Disord 2019; 246: 224-33.

32. Carter T, Bastounis A, Guo B, Jane Morrell C. The effectiveness of exercise-based interventions for preventing or treating postpartum depression: a systematic review and meta-analysis. Arch Womens Ment Health 2019; 22(1): 37-53.

33. Dennis CL, Creedy D. Psychosocial and psychological interventions for preventing postpartum depression. Cochrane Database Syst Rev 2004; (4): Cd001134.

34. Dennis CL. Psychosocial and psychological interventions for prevention of postnatal depression: systematic review. Bmj 2005; 331(7507): 15.

35. Dhillon A, Sparkes E, Duarte RV. Mindfulness-Based Interventions During Pregnancy: a Systematic Review and Meta-analysis. Mindfulness (N Y) 2017; 8(6): 1421-37.

36. Dodd JM, Dowswell T, Crowther CA. Specialised antenatal clinics for women with a multiple pregnancy for improving maternal and infant outcomes. Cochrane Database Syst Rev 2015; (11): Cd005300.

37. Dol J, Richardson B, Murphy GT, Aston M, McMillan D, Campbell-Yeo M. Impact of mobile health interventions during the perinatal period on maternal psychosocial outcomes: a systematic review. JBI Evid Synth 2020; 18(1): 30-55.

38. Geller PA, Stasko EC. Effect of Previous Posttraumatic Stress in the Perinatal Period. J Obstet Gynecol Neonatal Nurs 2017; 46(6): 912-22.

39. Hall HG, Cant R, Munk N, et al. The effectiveness of massage for reducing pregnant women's anxiety and depression; systematic review and meta-analysis. Midwifery 2020; 90: 102818.

40. Huang R, Yan C, Tian Y, et al. Effectiveness of peer support intervention on perinatal depression: A systematic review and meta-analysis. J Affect Disord 2020; 276: 788-96.

41. Lavender T, Richens Y, Milan SJ, Smyth RM, Dowswell T. Telephone support for women during pregnancy and the first six weeks postpartum. Cochrane Database Syst Rev 2013; (7): Cd009338.

42. Lin PZ, Xue JM, Yang B, Li M, Cao FL. Effectiveness of self-help psychological interventions for treating and preventing postpartum depression: a meta-analysis. Arch Womens Ment Health 2018; 21(5): 491-503.

43. Littleton HL, Breitkopf CR, Berenson AB. Correlates of anxiety symptoms during pregnancy and association with perinatal outcomes: a meta-analysis. Am J Obstet Gynecol 2007; 196(5): 424-32.

44. Meyrel M, Varin L, Detaint B, Mouaffak F. [The intestinal microbiota: A new player in depression?]. Encephale 2018; 44(1): 67-74.

45. O'Connor E, Senger CA, Henninger ML, Coppola E, Gaynes BN. Interventions to Prevent Perinatal Depression: Evidence Report and Systematic Review for the US Preventive Services Task Force. Jama 2019; 321(6): 588-601.

46. Poyatos-León R, García-Hermoso A, Sanabria-Martínez G, Álvarez-Bueno C, Cavero-Redondo I, Martínez-Vizcaíno V. Effects of exercise-based interventions on postpartum depression: A meta-analysis of randomized controlled trials. Birth 2017; 44(3): 200-8.

47. Shorey S, Chee CYI, Ng ED, Chan YH, Tam WWS, Chong YS. Prevalence and incidence of postpartum depression among healthy mothers: A systematic review and meta-analysis. J Psychiatr Res 2018; 104: 235-48.

48. Sockol LE, Epperson CN, Barber JP. Preventing postpartum depression: a meta-analytic review. Clin Psychol Rev 2013; 33(8): 1205-17.

49. Sockol LE. A systematic review of the efficacy of cognitive behavioral therapy for treating and preventing perinatal depression. J Affect Disord 2015; 177: 7-21.

50. Sockol LE. A systematic review and meta-analysis of interpersonal psychotherapy for perinatal women. J Affect Disord 2018; 232: 316-28.

51. Stuart S, O'Hara MW, Gorman LL. The prevention and psychotherapeutic treatment of postpartum depression. Arch Womens Ment Health 2003; 6 Suppl 2: S57-69.

52. Lever Taylor B, Cavanagh K, Strauss C. The Effectiveness of Mindfulness-Based Interventions in the Perinatal Period: A Systematic Review and Meta-Analysis. PLoS One 2016; 11(5): e0155720.

53. Tong P, Dong LP, Yang Y, Shi YH, Sun T, Bo P. Traditional Chinese acupuncture and postpartum depression: A systematic review and meta-analysis. J Chin Med Assoc 2019; 82(9): 719-26.

54. Warsiti W. The Effect of Maternal Role Intervention with Increased Maternal Role Identity Attainment in Pregnancy and Infant Growth: A Meta-analysis. Open Access Macedonian Journal of Medical Sciences 2020; 8(F): 287-92.

55. Wojcieszek AM, Shepherd E, Middleton P, et al. Care prior to and during subsequent pregnancies following stillbirth for improving outcomes. Cochrane Database Syst Rev 2018; 12(12): Cd012203.

56. Woody CA, Ferrari AJ, Siskind DJ, Whiteford HA, Harris MG. A systematic review and meta-regression of the prevalence and incidence of perinatal depression. J Affect Disord 2017; 219: 86-92.

57. Yonemoto N, Dowswell T, Nagai S, Mori R. Schedules for home visits in the early postpartum period. Cochrane Database Syst Rev 2017; 8(8): Cd009326.

58. Anderson FM, Hatch SL, Comacchio C, Howard LM. Prevalence and risk of mental disorders in the perinatal period among migrant women: a systematic review and meta-analysis. Arch Womens Ment Health 2017; 20(3): 449-62.

59. Azam S, Khanam A, Tirlapur S, Khan K. Planned caesarean section or trial of vaginal delivery? A meta-analysis. Curr Opin Obstet Gynecol 2014; 26(6): 461-8.

60. Beck CT. Postpartum depression: a metasynthesis. Qual Health Res 2002; 12(4): 453-72.

61. Brown HK, Qazilbash A, Rahim N, Dennis CL, Vigod SN. Chronic Medical Conditions and Peripartum Mental Illness: A Systematic Review and Meta-Analysis. Am J Epidemiol 2018; 187(9): 2060-8.

62. Chen S, Wang T, Zhang S, Zhao L, Chen L. Association between infertility treatment and perinatal depressive symptoms: A meta-analysis of observational studies. J Psychosom Res 2019; 120: 110-7.

63. Chowdhury R, Sinha B, Sankar MJ, et al. Breastfeeding and maternal health outcomes: a systematic review and meta-analysis. Acta Paediatr 2015; 104(467): 96-113.

64. Cuijpers P, Van Straten A, Smit F. Preventing the incidence of new cases of mental disorders: a meta-analytic review. J Nerv Ment Dis 2005; 193(2): 119-25.

65. Dachew BA, Ayano G, Alati R. Does weight gain during pregnancy influence antenatal depressive symptoms? A systematic review and meta-analysis. J Psychosom Res 2020; 138: 110255.

66. Dale J, Caramlau IO, Lindenmeyer A, Williams SM. Peer support telephone calls for improving health. Cochrane Database Syst Rev 2008; 2008(4): Cd006903.

67. Davenport MH, McCurdy AP, Mottola MF, et al. Impact of prenatal exercise on both prenatal and postnatal anxiety and depressive symptoms: a systematic review and meta-analysis. Br J Sports Med 2018; 52(21): 1376-85.

68. Dipietro L, Evenson KR, Bloodgood B, et al. Benefits of Physical Activity during Pregnancy and Postpartum: An Umbrella Review. Med Sci Sports Exerc 2019; 51(6): 1292-302.

69. González-Mesa E, Cuenca-Marín C, Suarez-Arana M, et al. Poor sleep quality is associated with perinatal depression. A systematic review of last decade scientific literature and meta-analysis. J Perinat Med 2019; 47(7): 689-703.

70. Hofmeyr GJ, Barrett JF, Crowther CA. Planned caesarean section for women with a twin pregnancy. Cochrane Database Syst Rev 2015; 2015(12): Cd006553.

71. Hösli I, Zanetti-Daellenbach R, Holzgreve W, Lapaire O. Role of omega 3-fatty acids and multivitamins in gestation. J Perinat Med 2007; 35 Suppl 1: S19-24.

72. Hutchens BF, Kearney J. Risk Factors for Postpartum Depression: An Umbrella Review. J Midwifery Womens Health 2020; 65(1): 96-108.

73. Luo Y, He GP. [Correlative analysis of postpartum depression]. Zhong Nan Da Xue Xue Bao Yi Xue Ban 2007; 32(3): 460-5.

74. Mersha AG, Abebe SA, Sori LM, Abegaz TM. Prevalence and Associated Factors of Perinatal Depression in Ethiopia: A Systematic Review and Meta-Analysis. Depress Res Treat 2018; 2018: 1813834.

75. O'Connor E, Rossom RC, Henninger M, et al. U.S. Preventive Services Task Force Evidence Syntheses, formerly Systematic Evidence Reviews. Screening for Depression in Adults: An Updated Systematic Evidence Review for the US Preventive Services Task Force. Rockville (MD): Agency for Healthcare Research and Quality (US); 2016.

76. O’Connor E, Senger CA, Henninger M, Gaynes BN, Coppola E, Soulsby Weyrich M. U.S. Preventive Services Task Force Evidence Syntheses, formerly Systematic Evidence Reviews. Interventions to Prevent Perinatal Depression: A Systematic Evidence Review for the US Preventive Services Task Force. Rockville (MD): Agency for Healthcare Research and Quality (US); 2019.

77. Owais S, Faltyn M, Johnson AVD, et al. The Perinatal Mental Health of Indigenous Women: A Systematic Review and Meta-Analysis. Can J Psychiatry 2020; 65(3): 149-63.

78. Park S, Kim J, Oh J, Ahn S. Effects of psychoeducation on the mental health and relationships of pregnant couples: A systemic review and meta-analysis. Int J Nurs Stud 2020; 104: 103439.

79. Robertson E, Grace S, Wallington T, Stewart DE. Antenatal risk factors for postpartum depression: a synthesis of recent literature. Gen Hosp Psychiatry 2004; 26(4): 289-95.

80. Suzuki D, Wariki WMV, Suto M, et al. Association of secondhand smoke and depressive symptoms in nonsmoking pregnant Women: A systematic review and meta-analysis. J Affect Disord 2019; 245: 918-27.

81. Upadhyay RP, Chowdhury R, Aslyeh S, et al. Postpartum depression in India: a systematic review and meta-analysis. Bull World Health Organ 2017; 95(10): 706-17c.

82. Yan H, Ding Y, Guo W. Mental Health of Pregnant and Postpartum Women During the Coronavirus Disease 2019 Pandemic: A Systematic Review and Meta-Analysis. Front Psychol 2020; 11: 617001.

83. Yonemoto N, Dowswell T, Nagai S, Mori R. Schedules for home visits in the early postpartum period. Cochrane Database Syst Rev 2013; (7): Cd009326.

84. Zhao XH, Zhang ZH. Risk factors for postpartum depression: An evidence-based systematic review of systematic reviews and meta-analyses. Asian J Psychiatr 2020; 53: 102353.

85. Austin MP, Priest SR, Sullivan EA. Antenatal psychosocial assessment for reducing perinatal mental health morbidity. Cochrane Database Syst Rev 2008; (4): Cd005124.

86. Ayano G, Tesfaw G, Shumet S. Prevalence and determinants of antenatal depression in Ethiopia: A systematic review and meta-analysis. PLoS One 2019; 14(2): e0211764.

87. Bastos MH, Furuta M, Small R, McKenzie-McHarg K, Bick D. Debriefing interventions for the prevention of psychological trauma in women following childbirth. Cochrane Database Syst Rev 2015; (4): Cd007194.

88. Chen J, Cross WM, Plummer V, Lam L, Tang S. A systematic review of prevalence and risk factors of postpartum depression in Chinese immigrant women. Women Birth 2019; 32(6): 487-92.

89. Dencker A, Nilsson C, Begley C, et al. Causes and outcomes in studies of fear of childbirth: A systematic review. Women Birth 2019; 32(2): 99-111.

90. Dennis CL, Kingston D. A systematic review of telephone support for women during pregnancy and the early postpartum period. J Obstet Gynecol Neonatal Nurs 2008; 37(3): 301-14.

91. Dennis CL, Ross LE, Herxheimer A. Oestrogens and progestins for preventing and treating postpartum depression. Cochrane Database Syst Rev 2008; 2008(4): Cd001690.

92. Duko B, Wolde D, Alemayehu Y. The epidemiology of postnatal depression in Ethiopia: a systematic review and meta-analysis. Reprod Health 2020; 17(1): 180.

93. Field T. Yoga research review. Complement Ther Clin Pract 2016; 24: 145-61.

94. Gilinsky AS, Dale H, Robinson C, Hughes AR, McInnes R, Lavallee D. Efficacy of physical activity interventions in post-natal populations: systematic review, meta-analysis and content coding of behaviour change techniques. Health Psychol Rev 2015; 9(2): 244-63.

95. De Giuseppe R, Roggi C, Cena H. n-3 LC-PUFA supplementation: effects on infant and maternal outcomes. Eur J Nutr 2014; 53(5): 1147-54.

96. Gould JF, Best K, Makrides M. Perinatal nutrition interventions and post-partum depressive symptoms. J Affect Disord 2017; 224: 2-9.

97. Hahn-Holbrook J, Cornwell-Hinrichs T, Anaya I. Economic and Health Predictors of National Postpartum Depression Prevalence: A Systematic Review, Meta-analysis, and Meta-Regression of 291 Studies from 56 Countries. Front Psychiatry 2017; 8: 248.

98. Ip S, Chung M, Raman G, et al. Breastfeeding and maternal and infant health outcomes in developed countries. Evid Rep Technol Assess (Full Rep) 2007; (153): 1-186.

99. Karaçam Z, Çoban A, Akbaş B, Karabulut E. Status of postpartum depression in Turkey: A meta-analysis. Health Care Women Int 2018; 39(7): 821-41.

100. Middleton P, Gomersall JC, Gould JF, Shepherd E, Olsen SF, Makrides M. Omega-3 fatty acid addition during pregnancy. Cochrane Database Syst Rev 2018; 11(11): Cd003402.

101. Miller BJ, Murray L, Beckmann MM, Kent T, Macfarlane B. Dietary supplements for preventing postnatal depression. Cochrane Database Syst Rev 2013; (10): Cd009104.

102. Molyneaux E, Telesia LA, Henshaw C, Boath E, Bradley E, Howard LM. Antidepressants for preventing postnatal depression. Cochrane Database Syst Rev 2018; 4(4): Cd004363.

103. Nilaweera I, Doran F, Fisher J. Prevalence, nature and determinants of postpartum mental health problems among women who have migrated from South Asian to high-income countries: a systematic review of the evidence. J Affect Disord 2014; 166: 213-26.

104. Øverland S, Woicik W, Sikora L, et al. Seasonality and symptoms of depression: A systematic review of the literature. Epidemiol Psychiatr Sci 2019; 29: e31.

105. Psarraki EE, Kokka I, Bacopoulou F, Chrousos GP, Artemiadis A, Darviri C. Is there a relation between major depression and hair cortisol? A systematic review and meta-analysis. Psychoneuroendocrinology 2021; 124: 105098.

106. Ribamar A, Almeida B, Soares A, et al. Relationship between vitamin D deficiency and both gestational and postpartum depression. Nutr Hosp 2020; 37(6): 1238-45.

107. Rollè L, Giordano M, Santoniccolo F, Trombetta T. Prenatal Attachment and Perinatal Depression: A Systematic Review. Int J Environ Res Public Health 2020; 17(8).

108. Ross LE, Campbell VL, Dennis CL, Blackmore ER. Demographic characteristics of participants in studies of risk factors, prevention, and treatment of postpartum depression. Can J Psychiatry 2006; 51(11): 704-10.

109. Saccone G, Saccone I, Berghella V. Omega-3 long-chain polyunsaturated fatty acids and fish oil supplementation during pregnancy: which evidence? J Matern Fetal Neonatal Med 2016; 29(15): 2389-97.

110. Scope A, Booth A, Morrell CJ, Sutcliffe P, Cantrell A. Perceptions and experiences of interventions to prevent postnatal depression. A systematic review and qualitative evidence synthesis. J Affect Disord 2017; 210: 100-10.

111. Scott KD, Klaus PH, Klaus MH. The obstetrical and postpartum benefits of continuous support during childbirth. J Womens Health Gend Based Med 1999; 8(10): 1257-64.

112. Tobin CL, Di Napoli P, Beck CT. Refugee and Immigrant Women's Experience of Postpartum Depression: A Meta-Synthesis. J Transcult Nurs 2018; 29(1): 84-100.

113. Villegas L, McKay K, Dennis CL, Ross LE. Postpartum depression among rural women from developed and developing countries: a systematic review. J Rural Health 2011; 27(3): 278-88.

114. Wilson LM, Reid AJ, Midmer DK, Biringer A, Carroll JC, Stewart DE. Antenatal psychosocial risk factors associated with adverse postpartum family outcomes. Cmaj 1996; 154(6): 785-99.

**Table S1. Biomarkers of postpartum depressive symptoms**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Biomarker** | **Author, year** | **Number of cases / total population** | **Number of study estimates** | **Study design** | **Effect metrics** | **Random effects summary estimate (95% CI)** | **Random effects p-value** | ***I2*** | **95% prediction interval** | **Large heterogeneity, small study effect, loss of significance under 10% credibility ceiling, or evidential value not found under p-curve analysis** | **AMSTAR 2** | **GRADE** |
| **Weak (class V)** | | | | | | | | | | | | |
| Serum 25(OH)D level < 50 nmol/l | Wang 2018 | 168 / 1432 | 3 | Cohort | OR | 4.51 (1.62 to 12.58) | 0.004 | 82% | 0 to 966649.84 | Large heterogeneity; loss of significance under 10% credibility ceiling; p curve analysis unavailable due to less than three significant studies | Critically low | Very low |
| High concentration of serum 25(OH)D | Tan 2020 | 404 / 2375 | 7 | Cohort, case-control, cross-sectional | RR | 0.48 (0.26 to 0.87) | 0.015 | 86% | 0.06 to 3.62 | Large heterogeneity; loss of significance under 10% credibility ceiling | Low | Very low |
| Omega-6/omega-3 ratio | Lin 2017 | 200 / 1741 | 5 | Cohort | Hedges' g | 0.35 (0.02 to 0.68) | 0.037 | 70% | -0.72 to 1.43 | Large heterogeneity; loss of significance under 10% credibility ceiling; p curve analysis unavailable due to less than three significant studies | Critically low | Very low |
| **Not significant (NS)** | | | | | | | | | | | | |
| Positive anti-thyroperoxidase antibodies | Minaldi 2020 | 201 / 2348 | 3 | Cohort | RR | 1.46 (0.76 to 2.77) | 0.25 | 71% | 0 to 2192.8 | Large heterogeneity | Critically low | Very low |
| Total omega-6 acid | Lin 2017 | 200 / 1741 | 5 | Cohort | Hedges' g | 0.13 (-0.02 to 0.27) | 0.079 | 0% | -0.11 to 0.36 | None | Critically low | Very low |
| Arachidonic acid | Lin 2017 | 200 / 1741 | 5 | Cohort | Hedges' g | 0.05 (-0.12 to 0.23) | 0.55 | 19% | -0.34 to 0.45 | None | Critically low | Very low |
| Eicosapentaenoic acid | Lin 2017 | 215 / 1793 | 6 | Cohort, case-control | Hedges' g | -0.08 (-0.25 to 0.1) | 0.39 | 23% | -0.46 to 0.31 | Small study effect | Critically low | Very low |
| Docosahexaenoic acid | Lin 2017 | 215 / 1793 | 6 | Cohort, case-control | Hedges' g | -0.2 (-0.49 to 0.08) | 0.17 | 66% | -1.06 to 0.66 | Large heterogeneity | Critically low | Low |
| Total omega-3 acid | Lin 2017 | 215 / 1793 | 6 | Cohort, case-control | Hedges' g | -0.24 (-0.51 to 0.03) | 0.085 | 63% | -1.04 to 0.56 | Large heterogeneity; small study effect | Critically low | Very low |
| All statistical tests are two-sided. Abbreviations: AMSTAR 2, A Measurement Tool to Assess Systematic Reviews 2; CI, confidence interval; GRADE, Grading of Recommendations, Assessment, Development and Evaluations; OR, odds ratio; RR, relative risk | | | | | | | | | | | | |

**Table S2. Sensitivity analyses of associations graded as convincing (class I) or highly suggestive (class II)**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Exposure** | **Author, year** | **Number of cases / total population** | **Number of study estimates** | **Effect metrics** | **Random effects summary estimate (95% CI)** | **Random effects p-value** | ***I2*** | **95% prediction interval** | **Large heterogeneity, small study effect, loss of significance under 10% credibility ceiling, or evidential value not found under p curve analysis** | **Level of evidence** |
| **After excluding individual studies using low cut-off symptom score** | | | | | | | | | | |
| Antenatal anxiety | Grigoriadis 2019 | 1023 / 11 758 | 7 | OR | 2·49 (1·91 to 3·25) | < 0 000001 | 12% | 1·54 to 4·04 | None | Convincing retained |
| Psychological violence | Zhang 2019 | 1018 / 6067 | 7 | OR | 2·05 (1.51 to 2·78) | 0·000004 | 43% | 0·95 to 4·43 | None | Convincing to suggestive |
| Intimate partner violence experience | Howard 2013 | 1055 / 7078 | 11 | OR | 2·93 (2.09 to 4·12) | < 0·000001 | 61% | 1·05 to 8·16 | Large heterogeneity; small study effect | Highly suggestive retained |
| Intimate partner violence during pregnancy | Beydoun 2012 | 4024 / 19 022 | 15 | RR | 3·12 (2.26 to 4·31) | < 0·000001 | 88% | 0·85 to 11·4 | Large heterogeneity; small study effect | Highly suggestive retained |
| Smoking during pregnancy | Chen 2019 | 2466 / 1 424 800 | 11 | OR | 2·39 (1.78 to 3·2) | < 0·000001 | 80% | 0·88 to 6·45 | Large heterogeneity | Highly suggestive retained |
| History of premenstrual syndrome | Cao 2020 | 1400 / 7573 | 18 | OR | 2·27 (1.84 to 2·82) | < 0·000001 | 44% | 1·19 to 4·36 | Small study effect | Highly suggestive retained |
| Any type of violence experience | Zhang 2019 | 11 056 / 122 705 | 30 | OR | 2·1 (1.71 to 2·58) | < 0·000001 | 93% | 0·74 to 5·95 | Large heterogeneity; small study effect | Highly suggestive retained |
| Primiparity compared to multiparity | Tokumitsu 2020 | 316 / 1995 | 4 | RR | 1·75 (1.17 to 2·64) | 0·0068 | 62% | 0·35 to 8·76 | Large heterogeneity; loss of significance under 10% credibility ceiling; p curve analysis unavailable due to less than three significant studies | Highly suggestive to weak |
| Unintended pregnancy | Qiu 2020 | 3754 / 42 098 | 27 | OR | 1·55 (1.33 to 1·81) | < 0·000001 | 66% | 0·82 to 2·93 | Large heterogeneity; small study effect | Highly suggestive retained |
| **Study estimates adjusted for at least one confounder** | | | | | | | | | | |
| Antenatal anxiety | Grigoriadis 2019 | 959 / 10 446 | 6 | OR | 2·48 (1.8 to 3·42) | < 0·000001 | 20% | 1·25 to 4·94 | None | Convincing to weak |
| Psychological violence | Zhang 2019 | 6720 / 59 060 | 7 | OR | 1·98 (1.55 to 2·52) | < 0·000001 | 54% | 1·05 to 3·74 | Large heterogeneity | Convincing to highly suggestive |
| Intimate partner violence during pregnancy | Beydoun 2012 | 6106 / 21 339 | 17 | RR | 2·81 (2.11 to 3·74) | < 0·000001 | 87% | 0·86 to 9·21 | Large heterogeneity; small study effect | Highly suggestive retained |
| Smoking during pregnancy | Chen 2019 | 73 / 163 | 1 | OR | 1·71 (1.01 to 2·89) | 0·045 | NA | NA | None | Highly suggestive to weak |
| History of premenstrual syndrome | Cao 2020 | 660 / 4205 | 7 | OR | 2·01 (1.6 to 2·53) | < 0·000001 | 13% | 1·33 to 3·04 | Small study effect | Highly suggestive to weak |
| Any type of violence experience | Zhang 2019 | 13 556 / 153 756 | 19 | OR | 1·79 (1.52 to 2·11) | < 0·000001 | 72% | 1 to 3·2 | Large heterogeneity | Highly suggestive retained |
| Primiparity compared to multiparity | Tokumitsu 2020 | 14 048 / 102 006 | 39 | RR | 1·76 (1.59 to 1·96) | < 0·000001 | 52% | 1·2 to 2·58 | Large heterogeneity; small study effect | Highly suggestive retained |
| Unintended pregnancy | Qiu 2020 | 4516 / 57534 | 17 | OR | 1·37 (1.21 to 1·55) | < 0·000001 | 71% | 0·91 to 2·06 | Large heterogeneity; small study effect | Highly suggestive retained |
| **Prospective or retrospective cohort only** | | | | | | | | | | |
| Antenatal anxiety | Grigoriadis 2019 | 1023 / 11758 | 7 | OR | 2·49 (1.91 to 3·25) | < 0·000001 | 12% | 1·54 to 4·04 | None | Convincing retained |
| Psychological violence | Zhang 2019 | 6734 / 59 132 | 8 | OR | 1·93 (1.54 to 2·42) | < 0·000001 | 48% | 1·1 to 3·4 | None | Convincing retained |
| Intimate partner violence experience | Howard 2013 | 275 / 2482 | 6 | OR | 2·87 (2.07 to 3·98) | < 0·000001 | 0% | 1·81 to 4·56 | None | Highly suggestive to weak |
| Smoking during pregnancy | Chen 2019 | 449 / 4451 | 5 | OR | 3·15 (1.41 to 7·02) | 0·0051 | 86% | 0·17 to 57·75 | Large heterogeneity | Highly suggestive to weak |
| History of premenstrual syndrome | Cao 2020 | 452 / 4442 | 6 | OR | 2·23 (1.74 to 2·86) | < 0·000001 | 10% | 1·42 to 3·51 | None | Highly suggestive to weak |
| Any type of violence experience | Zhang 2019 | 16 953 / 177 148 | 32 | OR | 2·04 (1.72 to 2·41) | < 0·000001 | 94% | 0·88 to 4·73 | Large heterogeneity; small study effect | Highly suggestive retained |
| Primiparity compared to multiparity | Tokumitsu 2020 | 12 109 / 88 073 | 9 | RR | 1·59 (1.37 to 1·85) | < 0·000001 | 54% | 1·08 to 2·36 | Large heterogeneity | Highly suggestive retained |
| Unintended pregnancy | Qiu 2020 | 5447 / 62 130 | 28 | OR | 1·53 (1.34 to 1·74) | < 0·000001 | 77% | 0·89 to 2·64 | Large heterogeneity; small study effect | Highly suggestive retained |
| **Prospective cohort only** | | | | | | | | | | |
| Antenatal anxiety | Grigoriadis 2019 | 960 / 11 183 | 6 | OR | 2·47 (1.98 to 3·09) | < 0·000001 | 0% | 1·8 to 3·39 | Small study effect | Convincing to weak |
| Psychological violence | Zhang 2019 | 6734 / 59 132 | 8 | OR | 1·93 (1.54 to 2·42) | < 0·000001 | 48% | 1·1 to 3·4 | None | Convincing retained |
| Intimate partner violence experience | Howard 2013 | 275 / 2482 | 6 | OR | 2·87 (2.07 to 3·98) | < 0·000001 | 0% | 1·81 to 4·56 | None | Highly suggestive to weak |
| Smoking during pregnancy | Chen 2019 | 449 / 4451 | 5 | OR | 3·15 (1.41 to 7·02) | 0·0051 | 86% | 0·17 to 57·75 | Large heterogeneity | Highly suggestive to weak |
| History of premenstrual syndrome | Cao 2020 | 195 / 1371 | 3 | OR | 2·13 (1.52 to 2·97) | 0·00001 | 0% | 0·24 to 18·62 | P curve analysis unavailable due to less than three significant studies | Highly suggestive to weak |
| Any type of violence experience | Zhang 2019 | 16 953 / 177 148 | 32 | OR | 2·04 (1.72 to 2·41) | < 0·000001 | 94% | 0·88 to 4·73 | Large heterogeneity; small study effect | Highly suggestive retained |
| Primiparity compared to multiparity | Tokumitsu 2020 | 12 109 / 88 073 | 9 | RR | 1·59 (1.37 to 1·85) | < 0·000001 | 54% | 1·08 to 2·36 | Large heterogeneity | Highly suggestive retained |
| Unintended pregnancy | Qiu 2020 | 3662 / 33 348 | 25 | OR | 1·63 (1.38 to 1·93) | < 0·000001 | 79% | 0·8 to 3·31 | Large heterogeneity; small study effect | Highly suggestive retained |
| All statistical tests are two-sided. Abbreviations: CI, confidence interval; OR, odds ratio; RR, relative risk | | | | | | | | | | |

**Table S3. Supplementary analyses result of environmental risk and protective factors**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Exposure** | **Author, year** | **Number of study estimates** | **Effect metrics** | **Fixed effects summary estimate (95% CI)** | **Fixed effects p-value** | **Effect estimate of the largest study (95% CI)** | **Egger p value** | **Summary estimate (95% CI) under 5/10/15/20% credibility ceilings** | ***I2* under 0/5/10/15/20% credibility ceilings** | **Right-skewness test of p curve analysis, p value for half curve / p value for full curve** |
| Antenatal anxiety | Grigoriadis 2019 | 7 | OR | 2**·**39 (1**·**92 to 2**·**96) | < 0**·**000001 | 2**·**1 (1**·**6 to 2**·**76) | 0**·**21 | 2**·**34 (1**·**48 to 3**·**7)/2**·**16 (1**·**25 to 3**·**72)/1**·**99 (1**·**07 to 3**·**7)/1**·**83 (0**·**92 to 3**·**64) | 12/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| Psychological violence | Zhang 2019 | 8 | OR | 1**·**75 (1**·**62 to 1**·**89) | < 0**·**000001 | 1**·**7 (1**·**56 to 1**·**85) | 0**·**38 | 1**·**65 (1**·**26 to 2**·**17)/1**·**62 (1**·**16 to 2**·**27)/1**·**59 (1**·**07 to 2**·**37)/1**·**56 (0**·**98 to 2**·**47) | 48/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| Intimate partner violence experience | Howard 2013 | 12 | OR | 2**·**43 (2**·**04 to 2**·**9) | < 0**·**000001 | 1**·**44 (1 to 2**·**07) | 0**·**021 | 2**·**02 (1**·**52 to 2**·**69)/2**·**02 (1**·**4 to 2**·**91)/2**·**02 (1**·**3 to 3**·**15)/2**·**02 (1**·**18 to 3**·**47) | 58/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| Intimate partner violence during pregnancy | Beydoun 2012 | 17 | RR | 2**·**01 (1**·**84 to 2**·**21) | < 0**·**000001 | 1**·**4 (1**·**21 to 1**·**62) | < 0**·**001 | 1**·**7 (1**·**42 to 2**·**04)/1**·**7 (1**·**35 to 2**·**14)/1**·**7 (1**·**28 to 2**·**26)/1**·**7 (1**·**19 to 2**·**42) | 87/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| Smoking during pregnancy | Chen 2019 | 11 | OR | 2**·**14 (1**·**9 to 2**·**41) | < 0**·**000001 | 2**·**21 (1**·**75 to 2**·**79) | 0**·**33 | 1**·**77 (1**·**39 to 2**·**26)/1**·**72 (1**·**29 to 2**·**3)/1**·**69 (1**·**2 to 2**·**39)/1**·**7 (1**·**12 to 2**·**58) | 80/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| History of premenstrual syndrome | Cao 2020 | 19 | OR | 2**·**01 (1**·**76 to 2**·**31) | < 0**·**000001 | 1**·**5 (1**·**09 to 2**·**07) | < 0**·**001 | 1**·**86 (1**·**52 to 2**·**28)/1**·**81 (1**·**41 to 2**·**31)/1**·**76 (1**·**32 to 2**·**33)/1**·**71 (1**·**23 to 2**·**39) | 42/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| Any type of violence experience | Zhang 2019 | 32 | OR | 1**·**45 (1**·**4 to 1**·**49) | < 0**·**000001 | 1**·**11 (1**·**06 to 1**·**16) | 0**·**013 | 1**·**43 (1**·**25 to 1**·**64)/1**·**24 (1**·**12 to 1**·**37)/1**·**23 (1**·**09 to 1**·**39)/1**·**22 (1**·**06 to 1**·**41) | 94/31/0/0/0% | < 0**·**001 / < 0**·**001 |
| Primiparity compared to multiparity | Tokumitsu 2020 | 39 | RR | 1**·**52 (1**·**47 to 1**·**56) | < 0**·**000001 | 1**·**46 (1**·**41 to 1**·**51) | 0**·**002 | 1**·**59 (1**·**42 to 1**·**78)/1**·**53 (1**·**34 to 1**·**75)/1**·**48 (1**·**28 to 1**·**72)/1**·**43 (1**·**21 to 1**·**7) | 52/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| Unintended pregnancy | Qiu 2020 | 30 | OR | 1**·**21 (1**·**17 to 1**·**26) | < 0**·**000001 | 1**·**11 (1**·**06 to 1**·**17) | < 0**·**001 | 1**·**24 (1**·**15 to 1**·**33)/1**·**23 (1**·**13 to 1**·**34)/1**·**22 (1**·**11 to 1**·**35)/1**·**21 (1**·**07 to 1**·**36) | 77/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| Intimate partner violence in the past year | Bacchus 2018 | 7 | OR | 1**·**74 (1**·**47 to 2**·**06) | < 0**·**000001 | 1**·**29 (1**·**02 to 1**·**63) | 0**·**17 | 1**·**66 (1**·**06 to 2**·**61)/1**·**42 (0**·**94 to 2**·**14)/1**·**26 (0**·**88 to 1**·**81)/1**·**18 (0**·**78 to 1**·**79) | 80/41/17/0/0% | < 0**·**001 / < 0**·**001 |
| Preterm birth | de Paula Eduardo 2019 | 12 | OR | 1**·**79 (1**·**44 to 2**·**23) | < 0**·**000001 | 1**·**29 (0**·**9 to 1**·**85) | 0**·**21 | 1**·**42 (1**·**11 to 1**·**81)/1**·**36 (1**·**05 to 1**·**76)/1**·**32 (0**·**98 to 1**·**77)/1**·**28 (0**·**92 to 1**·**78) | 66/1/0/0/0% | < 0**·**001 / < 0**·**001 |
| Perinatal anemia | Kang 2020 | 6 | RR | 2**·**04 (1**·**76 to 2**·**37) | < 0**·**000001 | 2**·**01 (1**·**7 to 2**·**38) | 0**·**87 | 1**·**88 (1**·**22 to 2**·**89)/1**·**76 (1**·**06 to 2**·**93)/1**·**64 (0**·**89 to 3**·**02)/1**·**64 (0**·**77 to 3**·**48) | 44/7/0/0/0% | < 0**·**001 / < 0**·**001 |
| Domestic violence | Zhang 2019 | 16 | OR | 2**·**15 (1**·**92 to 2**·**39) | < 0**·**000001 | 1**·**29 (1**·**02 to 1**·**63) | 0**·**83 | 1**·**5 (1**·**16 to 1**·**93)/1**·**36 (1**·**09 to 1**·**69)/1**·**31 (1**·**02 to 1**·**68)/1**·**26 (0**·**94 to 1**·**67) | 85/31/0/0/0% | < 0**·**001 / < 0**·**001 |
| Physical violence | Zhang 2019 | 8 | OR | 1**·**75 (1**·**47 to 2**·**08) | < 0**·**000001 | 1**·**4 (1**·**09 to 1**·**79) | 0**·**65 | 1**·**58 (1**·**2 to 2**·**08)/1**·**54 (1**·**1 to 2**·**16)/1**·**5 (1**·**01 to 2**·**23)/1**·**46 (0**·**93 to 2**·**29) | 59/0/0/0/0% | 0**·**004 / 0**·**001 |
| Immigration | Falah-Hassani 2015 | 5 | OR | 1**·**42 (1**·**28 to 1**·**56) | < 0**·**000001 | 1**·**3 (1**·**16 to 1**·**45) | 0**·**016 | 1**·**56 (1**·**16 to 2**·**09)/1**·**51 (1**·**08 to 2**·**13)/1**·**51 (0**·**99 to 2**·**3)/1**·**51 (0**·**9 to 2**·**54) | 71/5/0/0/0% | < 0**·**001 / < 0**·**001 |
| Sexual violence | Zhang 2019 | 6 | OR | 1**·**56 (1**·**35 to 1**·**81) | < 0**·**000001 | 1**·**6 (1**·**34 to 1**·**91) | 0**·**93 | 1**·**41 (1**·**09 to 1**·**82)/1**·**35 (1**·**02 to 1**·**78)/1**·**29 (0**·**96 to 1**·**74)/1**·**27 (0**·**89 to 1**·**82) | 17/0/0/0/0% | < 0**·**001 / 0**·**006 |
| Cesarean section | Moameri 2019 | 38 | OR | 1**·**27 (1**·**19 to 1**·**36) | < 0**·**000001 | 1**·**32 (1**·**14 to 1**·**53) | 0**·**19 | 1**·**17 (1**·**08 to 1**·**27)/1**·**14 (1**·**04 to 1**·**24)/1**·**11 (1**·**01 to 1**·**22)/1**·**09 (0**·**98 to 1**·**21) | 54/0/0/0/0% | 0**·**001 / < 0**·**001 |
| Pre-pregnancy obesity | Molyneaux 2014 | 14 | OR | 1**·**34 (1**·**27 to 1**·**41) | < 0**·**000001 | 1**·**43 (1**·**32 to 1**·**55) | 0**·**79 | 1**·**25 (1**·**07 to 1**·**46)/1**·**2 (1**·**02 to 1**·**41)/1**·**16 (0**·**96 to 1**·**39)/1**·**11 (0**·**91 to 1**·**36) | 48/7/0/0/0% | < 0**·**001 / < 0**·**001 |
| Elective cesarean section | Moameri 2019 | 28 | OR | 1**·**26 (1**·**16 to 1**·**36) | < 0**·**000001 | 1**·**32 (1**·**14 to 1**·**53) | 0**·**75 | 1**·**18 (1**·**06 to 1**·**31)/1**·**11 (0**·**99 to 1**·**24)/1**·**08 (0**·**96 to 1**·**21)/1**·**05 (0**·**93 to 1**·**19) | 48/3/0/0/0% | 0**·**06 / 0**·**002 |
| Poor social support | Tolossa 2020 | 5 | OR | 3**·**97 (3**·**33 to 4**·**72) | < 0**·**000001 | 1**·**83 (1**·**43 to 2**·**34) | 0**·**043 | 2**·**89 (1**·**42 to 5**·**88)/2**·**63 (1**·**18 to 5**·**84)/2**·**63 (0**·**98 to 7**·**05)/2**·**63 (0**·**78 to 8**·**86) | 96/6/0/0/0% | < 0**·**001 / < 0**·**001 |
| History of depression | Tolossa 2020 | 6 | OR | 4**·**99 (3**·**95 to 6**·**31) | < 0**·**000001 | 6**·**32 (3**·**96 to 10**·**09) | 0**·**11 | 2**·**34 (1**·**42 to 3**·**86)/2**·**2 (1**·**23 to 3**·**95)/2**·**2 (1**·**07 to 4**·**54)/2**·**2 (0**·**9 to 5**·**37) | 79/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| History of postpartum depression | Desta 2021 | 3 | OR | 4**·**82 (3**·**35 to 6**·**93) | < 0**·**000001 | 7**·**81 (4**·**47 to 13**·**65) | 0**·**22 | 3**·**36 (1**·**4 to 8**·**05)/3**·**36 (1**·**1 to 10**·**31)/3**·**36 (0**·**84 to 13**·**45)/3**·**36 (0**·**61 to 18**·**53) | 65/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| Poor sleep quality | Yang 2020 | 4 | OR | 4**·**04 (3**·**04 to 5**·**37) | < 0**·**000001 | 3**·**34 (2**·**04 to 5**·**47) | 0**·**95 | 2**·**41 (1**·**35 to 4**·**3)/2**·**41 (1**·**14 to 5**·**08)/2**·**41 (0**·**96 to 6**·**05)/2**·**41 (0**·**77 to 7**·**5) | 87/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| History of substance abuse | Desta 2021 | 3 | OR | 3**·**57 (2**·**64 to 4**·**84) | < 0**·**000001 | 5**·**42 (3**·**35 to 8**·**76) | 0**·**72 | 2**·**39 (1**·**22 to 4**·**66)/2**·**39 (1**·**01 to 5**·**64)/2**·**39 (0**·**82 to 6**·**91)/2**·**39 (0**·**64 to 8**·**84) | 82/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| History of infant death | Tolossa 2020 | 5 | OR | 3**·**63 (2**·**75 to 4**·**79) | < 0**·**000001 | 2**·**26 (1**·**45 to 3**·**52) | 0**·**84 | 2**·**44 (1**·**36 to 4**·**41)/2**·**26 (1**·**13 to 4**·**51)/2**·**1 (0**·**97 to 4**·**55)/1**·**95 (0**·**84 to 4**·**56) | 83/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| Poor marital relationship | Necho 2020 | 6 | OR | 3**·**84 (3**·**76 to 3**·**92) | < 0**·**000001 | 6 (5**·**79 to 6**·**21) | 0**·**25 | 2**·**96 (1**·**72 to 5**·**09)/2**·**96 (1**·**48 to 5**·**94)/2**·**96 (1**·**25 to 7)/2**·**96 (1**·**03 to 8**·**54) | 100/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| History of stressful life event | Necho 2020 | 2 | OR | 2**·**72 (2**·**15 to 3**·**43) | < 0**·**000001 | 2**·**4 (1**·**85 to 3**·**11) | NA | 2**·**81 (1**·**14 to 6**·**93)/2**·**81 (0**·**88 to 8**·**95)/2**·**81 (0**·**67 to 11**·**77)/2**·**81 (0**·**48 to 16**·**39) | 77/0/0/0/0% | NA / NA |
| Exposure to different types of intimate partner violence | Dadi 2020 | 10 | OR | 2**·**91 (2**·**42 to 3**·**51) | < 0**·**000001 | 3**·**1 (2**·**11 to 4**·**55) | 0**·**7 | 2**·**45 (1**·**72 to 3**·**49)/2**·**45 (1**·**55 to 3**·**85)/2**·**45 (1**·**4 to 4**·**29)/2**·**45 (1**·**23 to 4**·**89) | 17/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| History of mental disorders | Dadi 2020 | 5 | OR | 3**·**39 (2**·**95 to 3**·**9) | < 0**·**000001 | 4**·**42 (3**·**67 to 5**·**33) | 0**·**3 | 2**·**03 (1**·**09 to 3**·**8)/1**·**66 (0**·**89 to 3**·**1)/1**·**43 (0**·**74 to 2**·**77)/1**·**28 (0**·**63 to 2**·**6) | 85/25/4/0/0% | < 0**·**001 / < 0**·**001 |
| Low income | Necho 2020 | 3 | OR | 2**·**51 (1**·**75 to 3**·**59) | < 0**·**000001 | 2**·**3 (1**·**31 to 4**·**03) | 0**·**14 | 2**·**38 (1**·**29 to 4**·**4)/2**·**38 (1**·**08 to 5**·**25)/2**·**38 (0**·**9 to 6**·**32)/2**·**38 (0**·**71 to 7**·**93) | 4/0/0/0/0% | 0**·**028 / 0**·**004 |
| Adverse birth and infant health conditions | Dadi 2020 | 5 | OR | 2**·**06 (1**·**7 to 2**·**5) | < 0**·**000001 | 1**·**4 (1**·**04 to 1**·**88) | 0**·**25 | 1**·**69 (1**·**22 to 2**·**35)/1**·**69 (1**·**11 to 2**·**58)/1**·**69 (1**·**01 to 2**·**84)/1**·**69 (0**·**89 to 3**·**21) | 75/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| Postpartum anemia | Azami 2019 | 10 | RR | 1**·**54 (1**·**28 to 1**·**87) | 0**·**000008 | 1 (0**·**65 to 1**·**55) | 0**·**048 | 1**·**41 (1**·**01 to 1**·**96)/1**·**22 (0**·**92 to 1**·**61)/1**·**1 (0**·**86 to 1**·**41)/1**·**08 (0**·**82 to 1**·**42) | 75/39/15/0/0% | 0**·**007 / 0**·**003 |
| Poor obstetric conditions | Dadi 2020 | 8 | OR | 1**·**5 (1**·**35 to 1**·**66) | < 0**·**000001 | 1**·**35 (1**·**12 to 1**·**62) | 0**·**064 | 1**·**37 (1**·**17 to 1**·**61)/1**·**37 (1**·**12 to 1**·**69)/1**·**37 (1**·**07 to 1**·**77)/1**·**37 (1 to 1**·**88) | 71/0/0/0/0% | 0**·**024 / 0**·**002 |
| Pre-pregnancy underweight | Dachew 2021 | 5 | OR | 1**·**58 (1**·**38 to 1**·**82) | < 0**·**000001 | 1**·**52 (1**·**3 to 1**·**78) | 0**·**54 | 1**·**55 (1**·**12 to 2**·**14)/1**·**5 (1**·**02 to 2**·**21)/1**·**46 (0**·**95 to 2**·**26)/1**·**42 (0**·**88 to 2**·**3) | 45/0/0/0/0% | < 0**·**001 / < 0**·**001 |
| Gestational diabetes | Azami 2019 | 14 | RR | 1**·**67 (1**·**53 to 1**·**81) | < 0**·**000001 | 1**·**44 (1**·**26 to 1**·**65) | 0**·**87 | 1**·**31 (1**·**07 to 1**·**61)/1**·**25 (1**·**03 to 1**·**52)/1**·**23 (0**·**98 to 1**·**53)/1**·**2 (0**·**93 to 1**·**54) | 89/26/0/0/0% | < 0**·**001 / < 0**·**001 |
| Emergency cesarean section | Moameri 2019 | 10 | OR | 1**·**29 (1**·**14 to 1**·**46) | 0**·**000039 | 1**·**13 (0**·**97 to 1**·**32) | 0**·**083 | 1**·**19 (1**·**05 to 1**·**35)/1**·**18 (1**·**02 to 1**·**37)/1**·**18 (0**·**99 to 1**·**4)/1**·**18 (0**·**97 to 1**·**43) | 68/0/0/0/0% | < 0**·**001 / 0**·**001 |
| Childhood abuse | Zhang 2019 | 5 | OR | 1**·**59 (1**·**34 to 1**·**88) | < 0**·**000001 | 1**·**41 (1**·**1 to 1**·**81) | 0**·**65 | 1**·**46 (1**·**15 to 1**·**85)/1**·**42 (1**·**07 to 1**·**88)/1**·**39 (1**·**01 to 1**·**9)/1**·**36 (0**·**95 to 1**·**95) | 44/0/0/0/0% | 0**·**02 / 0**·**002 |
| HIV infection | Zhu 2019 | 10 | OR | 1**·**37 (1**·**11 to 1**·**68) | 0**·**0034 | 0**·**93 (0**·**63 to 1**·**37) | 0**·**11 | 1**·**28 (0**·**96 to 1**·**72)/1**·**16 (0**·**9 to 1**·**5)/1**·**08 (0**·**85 to 1**·**38)/1**·**03 (0**·**8 to 1**·**33) | 65/28/8/0/0% | 0**·**067 / 0**·**007 |
| Anemia during pregnancy | Azami 2019 | 8 | RR | 1**·**25 (1**·**07 to 1**·**47) | 0**·**0063 | 1**·**35 (0**·**98 to 1**·**87) | 0**·**93 | 1**·**19 (0**·**97 to 1**·**45)/1**·**14 (0**·**94 to 1**·**38)/1**·**13 (0**·**91 to 1**·**41)/1**·**12 (0**·**88 to 1**·**43) | 39/19/1/0/0% | NA / NA |
| Female infant compared to male infant | Ye 2020 | 29 | OR | 1 (0**·**97 to 1**·**04) | 0**·**99 | 0**·**97 (0**·**93 to 1**·**01) | 0**·**068 | 1 (0**·**93 to 1**·**08)/0**·**98 (0**·**94 to 1**·**02)/0**·**98 (0**·**93 to 1**·**03)/0**·**98 (0**·**93 to 1**·**04) | 75/19/0/0/0% | < 0**·**001 / 0**·**001 |
| Pre-pregnancy overweight | Dachew 2021 | 6 | OR | 1**·**08 (1**·**01 to 1**·**15) | 0**·**018 | 1**·**05 (0**·**98 to 1**·**13) | 0**·**19 | 1**·**07 (1 to 1**·**14)/1**·**06 (0**·**99 to 1**·**14)/1**·**07 (0**·**98 to 1**·**16)/1**·**07 (0**·**96 to 1**·**18) | 27/0/0/0/0% | NA / NA |
| Active husband participation in maternal healthcare/services during pregnancy | Yargawa 2015 | 2 | OR | 0**·**36 (0**·**23 to 0**·**56) | 0**·**000005 | 0**·**27 (0**·**15 to 0**·**49) | NA | 0**·**45 (0**·**22 to 0**·**91)/0**·**45 (0**·**18 to 1**·**12)/0**·**45 (0**·**14 to 1**·**39)/0**·**45 (0**·**11 to 1**·**8) | 48/0/0/0/0% | NA / NA |
| Active husband participation in maternal healthcare/services postpartum | Yargawa 2015 | 5 | OR | 0**·**38 (0**·**27 to 0**·**52) | < 0**·**000001 | 0**·**53 (0**·**34 to 0**·**83) | 0**·**49 | 0**·**43 (0**·**24 to 0**·**75)/0**·**42 (0**·**21 to 0**·**84)/0**·**46 (0**·**2 to 1**·**08)/0**·**48 (0**·**18 to 1**·**3) | 57/0/0/0/0% | 0**·**001 / 0**·**002 |
| Family history of mental illness | Necho 2020 | 2 | OR | 1**·**55 (0**·**99 to 2**·**43) | 0**·**057 | 1**·**2 (0**·**72 to 2**·**01) | NA | 1**·**63 (0**·**62 to 4**·**27)/1**·**36 (0**·**69 to 2**·**7)/1**·**26 (0**·**76 to 2**·**08)/1**·**24 (0**·**75 to 2**·**06) | 75/44/12/0/0% | NA / NA |
| Labor epidural analgesia | Kountanis 2020 | 10 | OR | 1**·**03 (0**·**89 to 1**·**19) | 0**·**73 | 0**·**86 (0**·**69 to 1**·**07) | 0**·**85 | 1**·**1 (0**·**8 to 1**·**51)/1**·**09 (0**·**81 to 1**·**45)/0**·**99 (0**·**8 to 1**·**24)/1 (0**·**77 to 1**·**31) | 79/48/26/0/0% | 0**·**011 / 0**·**001 |
| All statistical tests are two-sided. Abbreviations: CI, confidence interval; HIV, human immunodeficiency virus; NA, not available; OR,odds ratio; RR, relative risk | | | | | | | | | | |

Table S4. Grading of Recommendations, Assessment, Development and Evaluations appraisal for environmental risk and protective factors

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Environmental risk/protective factor** | **Author, year** | **k** | **Study design** | **Risk of bias** | **Inconsistency** | **Indirectness** | **Imprecision** | **Publication bias** | **Other considerations** | **Certainty** | |
| Antenatal anxiety | Grigoriadis 2019 | 7 | Cohort | Not Serious | Not serious | Not serious | Not serious | Not likely | Large effect | Moderate |
| Psychological violence | Zhang 2019 | 8 | Cohort | Not Serious | Not serious | Not serious | Not serious | Not likely |  | Low |
| Intimate partner violence experience | Howard 2013 | 12 | Cohort, cross-sectional | Not Serious | Serious | Not serious | Not serious | Likely | Large effect | Very low |
| Intimate partner violence during pregnancy | Beydoun 2012 | 17 | Cross-sectional | Serious | Very Serious | Not serious | Not serious | Not likely | Large effect | Very low |
| Smoking during pregnancy | Chen 2019 | 11 | Cohort, case-control, cross-sectional | Serious | Very Serious | Not serious | Not serious | Not likely | Large effect | Very low |
| History of premenstrual syndrome | Cao 2020 | 19 | Cohort, case-control, cross-sectional | Very serious | Not serious | Not serious | Not serious | Not likely | Large effect | Very low |
| Any type of violence experience | Zhang 2019 | 32 | Cohort | Not Serious | Very Serious | Not serious | Not serious | Likely | Large effect | Very low |
| Primiparity compared to multiparity | Tokumitsu 2020 | 39 | Cohort, case-control, cross-sectional | Serious | Serious | Not serious | Not serious | Likely |  | Very low |
| Unintended pregnancy | Qiu 2020 | 30 | Cohort, case-control | Not Serious | Very Serious | Not serious | Not serious | Not likely |  | Very low |
| History of mental disorders | Dadi 2020 | 5 | Cohort, cross-sectional | Not Serious | Very Serious | Not serious | Not serious | Not likely | Large effect | Very low |
| Intimate partner violence in the past year | Bacchus 2018 | 7 | Cohort | Serious | Very Serious | Not serious | Not serious | Not likely | Large effect | Very low |
| Preterm birth | de Paula Eduardo 2019 | 12 | Cohort, case-control, cross-sectional | Not Serious | Serious | Not serious | Not serious | Not likely | Large effect | Low |
| Perinatal anemia | Kang 2020 | 6 | Cohort, case-control | Serious | Not serious | Not serious | Not serious | Not likely | Large effect | Low |
| Domestic violence | Zhang 2019 | 16 | Cohort | Not Serious | Very Serious | Not serious | Not serious | Not likely | Large effect | Very low |
| Physical violence | Zhang 2019 | 8 | Cohort | Not Serious | Serious | Not serious | Not serious | Likely |  | Very low |
| Immigration | Falah-Hassani 2015 | 5 | Cohort, cross-sectional | Not Serious | Serious | Not serious | Not serious | Not likely |  | Very low |
| Pre-pregnancy underweight | Dachew 2021 | 5 | Cohort | Not Serious | Not serious | Not serious | Not serious | Not likely |  | Low |
| Sexual violence | Zhang 2019 | 6 | Cohort | Not Serious | Not serious | Not serious | Not serious | Not likely |  | Low |
| Cesarean section | Moameri 2019 | 38 | Cohort, case-control | Not Serious | Serious | Not serious | Not serious | Not likely |  | Very low |
| Pre-pregnancy obesity | Molyneaux 2014 | 14 | Cohort, cross-sectional | Not Serious | Not serious | Not serious | Not serious | Likely |  | Very low |
| Elective cesarean section | Moameri 2019 | 28 | Cohort, case-control | Not Serious | Not serious | Not serious | Not serious | Not likely |  | Low |
| Poor social support | Tolossa 2020 | 5 | Cross-sectional | Not Serious | Very Serious | Not serious | Not serious | Not likely | Very large effect | Low |
| History of depression | Tolossa 2020 | 6 | Cross-sectional | Not Serious | Very Serious | Not serious | Not serious | Not likely | Large effect | Very low |
| History of postpartum depression | Desta 2021 | 3 | Cross-sectional | Not Serious | Serious | Not serious | Not serious | Not likely | Large effect | Low |
| Poor sleep quality | Yang 2020 | 4 | Cross-sectional | Not Serious | Very Serious | Not serious | Not serious | Not likely | Large effect | Very low |
| History of substance abuse | Desta 2021 | 3 | Cross-sectional | Not Serious | Very Serious | Not serious | Not serious | Not likely | Large effect | Very low |
| History of infant death | Tolossa 2020 | 5 | Cross-sectional | Not Serious | Very Serious | Not serious | Not serious | Not likely | Large effect | Very low |
| Poor marital relationship | Necho 2020 | 6 | Cross-sectional | Not Serious | Very Serious | Not serious | Not serious | Not likely | Large effect | Very low |
| History of stressful life event | Necho 2020 | 2 | Cross-sectional | Not Serious | Very Serious | Not serious | Not serious | Not likely | Large effect | Very low |
| Exposure to different types of intimate partner violence | Dadi 2020 | 10 | Cohort, cross-sectional | Not Serious | Not serious | Not serious | Not serious | Not likely | Large effect | Moderate |
| Low income | Necho 2020 | 3 | Cross-sectional | Not Serious | Not serious | Not serious | Not serious | Not likely | Large effect | Moderate |
| Adverse birth and infant health conditions | Dadi 2020 | 5 | Cohort, cross-sectional | Not Serious | Serious | Not serious | Not serious | Likely | Large effect | Very low |
| Postpartum anemia | Azami 2019 | 10 | Cohort, cross-sectional | Not Serious | Serious | Not serious | Not serious | Not likely |  | Very low |
| Poor obstetric conditions | Dadi 2020 | 8 | Cohort, cross-sectional | Not Serious | Serious | Not serious | Not serious | Not likely |  | Very low |
| Gestational diabetes | Azami 2019 | 14 | Cohort, case-control, cross-sectional | Not Serious | Very Serious | Not serious | Not serious | Not likely |  | Very low |
| Emergency cesarean section | Moameri 2019 | 10 | Cohort, case-control | Not Serious | Serious | Not serious | Not serious | Not likely |  | Very low |
| Childhood abuse | Zhang 2019 | 5 | Cohort | Not Serious | Not serious | Not serious | Not serious | Not likely |  | Low |
| HIV infection | Zhu 2019 | 10 | Cohort, case-control, cross-sectional | Not Serious | Serious | Not serious | Not serious | Not likely |  | Very low |
| Anemia during pregnancy | Azami 2019 | 8 | Cohort | Not Serious | Not serious | Not serious | Not serious | Not likely |  | Low |
| Female infant compared to male infant | Ye 2020 | 29 | Cohort, case-control | Not Serious | Serious | Not serious | Not serious | Not likely |  | Very low |
| Pre-pregnancy overweight | Dachew 2021 | 6 | Cohort | Not Serious | Not serious | Not serious | Not serious | Not likely |  | Low |
| Active husband participation in maternal healthcare/services during pregnancy | Yargawa 2015 | 2 | Cohort, cross-sectional | Not Serious | Not serious | Not serious | Not serious | Likely | Large effect | Low |
| Active husband participation in maternal healthcare/services postpartum | Yargawa 2015 | 5 | Cohort, case-control, cross-sectional | Not Serious | Serious | Not serious | Not serious | Not likely | Large effect | Low |
| Family history of mental illness | Necho 2020 | 2 | Cross-sectional | Not Serious | Serious | Not serious | Serious | Not likely |  | Very low |
| Labor epidural analgesia | Kountanis 2020 | 10 | Cohort, case-control | Serious | Very Serious | Not serious | Serious | Not likely |  | Very low |
| Abbreviations: HIV, human immunodeficiency virus; k, number of study estimates | | | | | | | | | | | |

Table S5. Grading of Recommendations, Assessment, Development and Evaluations appraisal for biomarkers s

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Biomarkers** | **Author, year** | **k** | **Study design** | **Risk of bias** | **Inconsistency** | **Indirectness** | **Imprecision** | **Publication bias** | **Other considerations** | **Certainty** |
| Serum 25(OH)D level < 50 nmol/l | Wang 2018 | 3 | Cohort | Not serious | Very serious | Not serious | Not serious | Not likely | Large effect | Very low |
| High concentration of serum 25(OH)D | Tan 2020 | 7 | Cohort, case-control, cross-sectional | Not serious | Very serious | Not serious | Not serious | Not likely |  | Very low |
| Omega-6/omega-3 ratio | Lin 2017 | 5 | Cohort | Not serious | Serious | Not serious | Not serious | Not likely |  | Very low |
| Positive anti-thyroperoxidase antibodies | Minaldi 2020 | 3 | Cohort | Not serious | Serious | Not serious | Serious | Not likely |  | Very low |
| Total omega-6 acid | Lin 2017 | 5 | Cohort | Not serious | Not serious | Not serious | Serious | Not likely |  | Very low |
| Arachidonic acid | Lin 2017 | 5 | Cohort | Not serious | Not serious | Not serious | Serious | Not likely |  | Very low |
| Eicosapentaenoic acid | Lin 2017 | 6 | Cohort, case-control | Not serious | Not serious | Not serious | Serious | Likely |  | Very low |
| Docosahexaenoic acid | Lin 2017 | 6 | Cohort, case-control | Not serious | Serious | Not serious | Serious | Not likely | Large effect | Low |
| Total omega-3 acid | Lin 2017 | 6 | Cohort, case-control | Not serious | Serious | Not serious | Serious | Likely | Large effect | Very low |
| Abbreviations: k, number of study estimates | | | | | | | | | | |

**Figure S1. Antenatal anxiety (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

A picture containing chart

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generateds

**Figure S2. Psychological violence (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

A picture containing table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S3. Intimate partner violence experience (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S4. Intimate partner violence during pregnancy (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated with medium confidence

**Figure S5. Smoking during pregnancy (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S6. History of premenstrual syndrome (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S7. Any type of violence (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Chart

Description automatically generated with medium confidence

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S8. Primiparity compared to multiparity (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Chart

Description automatically generated with medium confidence

2) Funnel plot

Chart, radar chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S9. Unintended pregnancy (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Chart

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Line chart

Description automatically generated

**Figure S10. History of mental disorders (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated with low confidence

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Line chart

Description automatically generated with low confidence

**Figure S11. Intimate partner violence in the past year (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S12. Preterm birth (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Chart

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S13. Perinatal anemia (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart, radar chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S14. Domestic violence (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

A picture containing chart

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S15. Physical violence (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Chart

Description automatically generated

2) Funnel plot

Chart, radar chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S16. Immigration (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S17. Pre-pregnancy underweight (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S18. Sexual violence (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated with medium confidence

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S19. Cesarean section (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Chart

Description automatically generated

2) Funnel plot

Chart, radar chart

Description automatically generated

3) P curve analysis plot

Graphical user interface, chart, line chart

Description automatically generated

**Figure S20. Pre-pregnancy obesity (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Chart, box and whisker chart

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S21. Elective cesarean section (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Chart

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S22. Poor social support (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

A picture containing text, boat, screenshot

Description automatically generated

3) P curve analysis plot

Line chart

Description automatically generated with medium confidence

**Figure S23. History of depression (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S24. History of postpartum depression (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

A picture containing chart

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S25. Poor sleep quality (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S26. History of substance abuse (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

A picture containing chart

Description automatically generated

2) Funnel plot

A picture containing chart

Description automatically generated

3) P curve analysis plot

Line chart

Description automatically generated with medium confidence

**Figure S27. History of infant death (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

A picture containing table

Description automatically generated

2) Funnel plot

Chart, radar chart

Description automatically generated

3) P curve analysis plot

Line chart

Description automatically generated with low confidence

**Figure S28. Poor marital relationship (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated with low confidence

2) Funnel plot

A picture containing text, boat, screenshot

Description automatically generated

3) P curve analysis plot

Line chart

Description automatically generated with low confidence

**Figure S29. History of stressful life event (Forest plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Not available because of the small number of studies

3) P curve analysis plot

Not available because of the small number of studies

**Figure S30. Exposure to different types of intimate partner violence (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Line chart

Description automatically generated with medium confidence

**Figure S31. Low income (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Chart

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S32. Adverse birth and infant health conditions (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S33. Postpartum anemia (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

A picture containing chart

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S34. Poor obstetric conditions (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S35. Gestational diabetes (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Chart

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S36. Emergency cesarean section (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Chart

Description automatically generated with low confidence

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S37. Childhood abuse (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated with medium confidence

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S38. HIV infection (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

A picture containing chart

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S39. Anemia during pregnancy (Forest plot, funnel plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Not available because of the small number of studies

**Figure S40. Female infant compared to male infant (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Chart

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S41. Pre-pregnancy overweight (Forest plot, funnel plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart, radar chart

Description automatically generated

3) P curve analysis plot

Not available because of the small number of studies

**Figure S42. Active husband participation in maternal healthcare/services during pregnancy (Forest plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Not available because of the small number of studies

3) P curve analysis plot

Not available because of the small number of studies

**Figure S43. Active husband participation in maternal healthcare/services postpartum (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart, diagram

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S44. Family history of mental illness (Forest plot)**

1) Forest plot

A picture containing diagram

Description automatically generated

2) Funnel plot

Not available because of the small number of studies

3) P curve analysis plot

Not available because of the small number of studies

**Figure S45. Labor epidural analgesia (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Chart

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Line chart

Description automatically generated with low confidence

**Figure S46. Serum 25(OH)D level < 50 nmol/L (Forest plot, funnel plot)**

1) Forest plot

A picture containing chart

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Not available because of the small number of studies

**Figure S47. High concentration of serum 25(OH)D (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

A picture containing diagram

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Chart, line chart

Description automatically generated

**Figure S48. Omega-6/omega-3 ratio (Forest plot, funnel plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Not available because of the small number of studies

**Figure S49. Positive anti-thyroperoxidase antibodies (Forest plot, funnel plot, p curve analysis plot)**

1) Forest plot

Chart

Description automatically generated with medium confidence

2) Funnel plot

Chart, diagram

Description automatically generated

3) P curve analysis plot

Not available because of the small number of studies

**Figure S50. Total omega-6 acid (Forest plot, funnel plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart, radar chart

Description automatically generated

3) P curve analysis plot

Not available because of the small number of studies

**Figure S51. Arachidonic acid (Forest plot, funnel plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Not available because of the small number of studies

**Figure S52. Eicosapentaenoic acid (Forest plot, funnel plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Not available because of the small number of studies

**Figure S53. Docosahexaenoic acid (Forest plot, funnel plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart, radar chart

Description automatically generated

3) P curve analysis plot

Not available because of the small number of studies

**Figure S54. Total omega-3 acid (Forest plot, funnel plot)**

1) Forest plot

Table

Description automatically generated

2) Funnel plot

Chart

Description automatically generated

3) P curve analysis plot

Not available because of the small number of studies