Review Article

Association between Vitamin D Levels During Pregnancy and Postpartum Depression: A Narrative Reviews

Abstract

Background: Postpartum Depression (PPD) is a serious depression that develops in the first year, with unknown explained reasons. Many studies evaluated the impact of Vitamin D (VD) levels on depression during pregnancy and postnatal. This narrative review aims to review any association between serum VD levels during pregnancy and the development of PPD. **Materials and Methods:** PPD data from published trials and research articles (period from 2012 to 2022) were assessed through PubMed, Scopus, Science Direct, and Google Scholar using the following terms: Depression, pregnancy, 25-hydroxyvitamin D (25OH VD), vitamin D deficiency (VDD) and postpartum (PP). Articles were selected manually and with careful tracking to avoid duplication. Articles that investigated any association between VD levels during pregnancy and PPD in the time frame were included in the study, while articles investigating VD levels of PP without depression were excluded. **Results:** In this narrative review, five out of seven studies showed an association between PPD and VDD during pregnancy. Danish National Birth Cohort (DNBC), Edinburgh Postnatal Depression Scale (EPDS) and Center for Epidemiologic Studies Depression Scale (CES-D) enrolled among different studies from 3 days to 1 year PP to assess PPD. **Conclusions:** Pregnant women with VDD are significantly associated with PPD. Longitudinal follow-up studies are needed to evaluate the association between VDD with PPD. Screening VD levels among pre-postnatal mothers may be essential for awareness programs that can be implemented to promote remission of postnatal depression.

Keywords: *25-hydroxyvitamin D, depression, pregnancy, vitamin D deficiency*

Sajedah Bateineh[1], Manar Fayiz Atoum[2]

[1]Department of Medical Laboratory Sciences, Faculty of Applied Health Sciences, The Hashemite University, Zarqa, Jordan, [2]Department of Medical Laboratory Sciences, Faculty of Applied Health Sciences, The Hashemite University, Zarqa, Jordan

Introduction

Postpartum Depression (PPD) is one of the most serious depression subtypes that is considered a major public health issue.[1] It is a nonpsychotic depressive event that develops following childbirth and progresses in the first year following delivery.[2,3] Worldwide, up to 20% of women have PPD within the first year following childbirth.[4,5] The prevalence of PPD varies between different countries[6] and has been estimated between 100 and 150 per 1000 births varied according to cultural and societal factors.[7] According to epidemiological statistics, the prevalence was predicted around 8.5% in Canada, 5–13.4% in Denmark, 13–19% in the USA, and 13.4–36% in Brazil and Chile.[7,8] In the Middle East, PPD is common (27%), and bad economy and problems related to pregnancy, low educational levels, unplanned pregnancy, and lack of social support[9] represent significant risk factors.

Features of PPD disorder include contemplative ruminations, panic attacks,[10] emotional instability, tearfulness, lack of appetite, sleeping problems, poor focus, exhaustion, impatience, melancholy, thoughts of suicide, and a sense of blame. Also includes moods of insufficiency and the inability to care for the newborn.[7,11] These signs may last from a few weeks to more than 6 months.[12] Depression negatively influences women's lives, their families, and the baby's cognitive and behavioral development.[13,14] The definite cause of PPD is unknown,[15] even though multiple biological, genetic, socioeconomic, and physiological variables pool to cause this condition.[13,16] PPD development is prone to a number of risk factors, which include depression during pregnancy,[17,18] high stress levels, an absence of financial support, a poor education, and challenging

How to cite this article: Bateineh S, Atoum MF. Association between vitamin D levels during pregnancy and postpartum depression: A narrative reviews. Iran J Nurs Midwifery Res 2024;29:290-6.

Submitted: 15-Feb-2023. **Revised:** 04-Feb-2024. **Accepted:** 20-Feb-2024. **Published:** 02-Jul-2024.

Address for correspondence:
Prof. Manar Fayiz Atoum, The Hashemite University/ Faculty of Applied Health Sciences, P.O. Box 330127, Zarqa 13133, Jordan.
E-mail: manar@hu.edu.jo

Access this article online

Website: https://journals.lww.com/jnmr

DOI: 10.4103/ijnmr.ijnmr_49_23

Quick Response Code:

birth experience,[18,19] and dietary factors like Vitamin D Deficiency (VDD) and polyunsaturated fatty acids.[1] Many self-report tests can be used to check for PPD such as the Edinburgh Postnatal Depression Scale (EPDS),[20] but a clinical interview is the standard method for its diagnoses.[21]

Although the cause of PPD is unclear, publications showed that it may be associated with a psycho-neuro-immune component,[7,22] and three hypotheses were developed: The first one, PPD has been linked to a decrease in the brain's production of monoamine neurotransmitters, one of these monoamines is serotonin.[23] Biological estrogens estradiol and estriol are released by the placenta and increase during pregnancy. Serotonin function is increased by estradiol and is significantly linked to mood disorders, estradiol levels increase significantly throughout pregnancy and drop abruptly after delivery, this fast decline in estradiol level may be a factor in complicated PPD.[10,24] The second one, is that stress triggers the hypothalamus to rerelease Corticotrophin-Releasing Hormone (CRH),, that triggers the release of corticotrophins from pituitary, and generate cortisol. PPD is caused by a malfunction in the hypothalamic-pituitary-adrenal alignment and involves many abnormalities, including the increase in cortisol levels during pregnancy and subsequent sharp decline after delivery.[24,25] The third one is the association between the development of PPD and some cytokines like interleukin-6 and tumor necrosis factor.[7,25] Therefore, the association between Vitamin D (VD) and PPD development must be intensely understood through *in vitro* and *in vivo* studies. This will offer treatment guidance with simple and low coastlines.

VD is a steroid hormone that is produced by our bodies after being exposed to ultraviolet B radiation through the skin,[26] it can also be acquired from food like fish, egg yolk, liver oil, beef liver, portabella mushrooms, fortified foods such as breakfast cereal and milk.[27–29] Ultraviolet light converts 7-dehydrocholesterol to pre- VD, which is convert to cholecalciferol (VD3),[24] that exhibits no biological activity within the body. Then it passes through two hydroxylation steps to be activated, the first one in the liver to produce 25hydroxy vitamin D (25(OH)D), which is the predominant vitamin form in our blood,[30] and the second hydroxylation occur mainly inside the kidney, brain, and immune system by 1alpha-hydroxylase using specialized cells to produce the functional form of VD, which is called calcitriol. Serum 25(OH)D levels lower than 25 nmol/L (10 ng/mL) are considered as VDD, serum VD lower than 50 nmol/L (20 ng/mL) is considered as VD insufficiency, while VD higher than 100 nmol/L (40 ng/mL) is defined as vitamin sufficiency.[31]

Vitamin D Receptor (VDR) has hormone-binding and DNA-binding domains.[1,18] VDR are widely distributed among nearly all human tissues and cells and perform many functions[4,32]; VD functions *via* endocrine (calcemic), keeps the calcium homeostasis, and autocrine (non-calcemic) functions.[1,33] VD is also involved in bone metabolism,[34] neuromuscular, and immune function that reduces inflammation associated with multiple sclerosis, autoimmune disorders, respiratory disease, and cancer.[27,35]

VD is an exceptional neuro-steroid hormone,[36,37] and its receptors were widely distributed throughout several areas of the brain including the basal ganglia, hypothalamus, thalamus cingulate, cortex, and hippocampus, which might influence the etiology of depression.[38,39] VDR and the enzyme responsible for producing the active version of the hormone 1alpha-hydroxylase both exist in the human brain and the hypothalamic-pituitary-adrenal alignment that may explain the association between VDD and depression.[40] The mechanism of how a low VD concentration may lead to depression includes a few suggestions correlated with the neurotransmission and neurogenesis functions of VD and the production of brain tryptophan hydroxylase2.[4] This influences the production of serotonin, which is highly connected with social behavior.[1,4] Another suggestion is that VD prevents the hypermethylation of gene promoters, which are crucial for Gamma-amino butyric acid-ergic neuron function. This clarifies the association between the reduction in the quantity of GABA-ergic neurons and depression.[4,41] Many studies evaluate the influence of VD supplements in improving depressive symptoms and decreasing their severity.[3,42] Increased circulating 25(OH)D concentrations following 8-week VD supplementation (50,000 IU) resulted in a significant decrease in Beck Depression Inventory-II (BDI-II) scores in patients with mild-to-moderate depression.[42] The relationship between VD levels and PPD is controversial; few studies revealed the association between VD level and PPD,[7,13,29,43] while others showed no association.[7] This study aims to review the studies concerning the association between 25(OH)D levels during pregnancy and PPD development.

Materials and Methods

Literature review used PubMed, Scopus, Science Direct, and Google Scholar for studies (July 1912 to May 2022). Keywords featuring a combination of depression, VD, pregnancy, PP, and antepartum were selected for search. This study reviewed the previous studies regarding the association between VD levels during pregnancy and PPD. Studies were enrolled only if they were published in the English language and if VD serum level was measured before the day of delivery (during the gestation period). Although more than 100 publications (case-control, prospective cohort, and longitudinal cohort) were fully checked, only seven were valid by the inclusion criteria [Figure 1]. Articles were selected manually and with careful tracking for inclusion criteria. All articles that investigated the relationship between VD level during

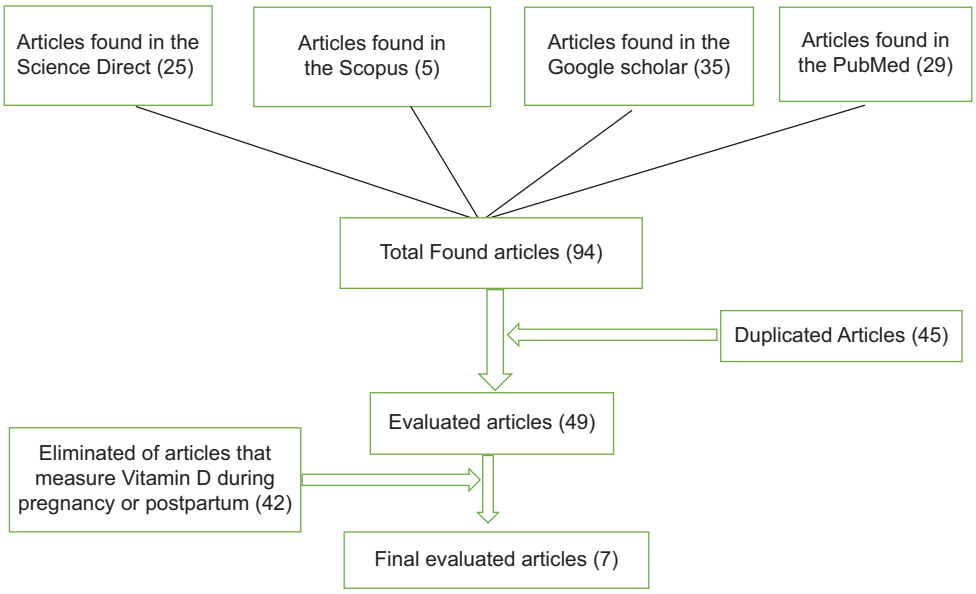

Figure 1: The flowchart for the selection process of the articles

pregnancy and PPD were enrolled in this study. All articles that investigated VD levels of PP were excluded. Data collected from the enrolled studies must include publication year, authors, sample size, phase for serum sample collection, PPD assessment method, and full results description. [Table 1]. The authors tried to act in an unbiased way while analyzing the retrieved data from the enrolled articles. For ethical considerations, the researchers avoided plagiarism in any form and avoided redundant publication. In the current study, ethical principles have been considered, and if the study results were utilized, the studies were referenced.

Ethical considerations

This study was approved by the Ethical Committee (IRB) at the Hashemite University, Zarqa, Jordan (IRB/12-2/2022).

Results

Only seven published articles from the literature reviewed using PubMed, Scopus, Science Direct, and Google Scholar search engine, keywords selected a combination of depression, VD, pregnancy, postpartum (PP), and antepartum showed an association between VD level and PPD throughout pregnancy period [Table 1]. The firstborn one is by Nielsen *et al*.,[43] who examined the association between PPD and VD levels. Participants (605 cases, 875 control) were selected from the Danish National Birth Cohort (DNBC). Blood samples were selected within week 25 of pregnancy, and the study used Liquid chromatography-Tandem Mass Spectrometry (LCTMS) for measuring VD levels. VD concentration was categorized into groups (less than 6 ng/mL, 6–9.6 ng/mL, 10–19.6 ng/mL, 20–31.7 ng/mL, 32–39.7 ng/mL, more than 40 ng/mL). VD 20–31.7 ng/mL were designated as a reference. DNBC were used in depression assessment. Nielsen *et al*.[43] showed no significant association between VD levels and the risk of PPD ($p = 0.08$). Conversely, they showed that high VD concentrations were associated with a higher risk of PPD.

The second study was a prospective cohort that was carried out by Robinson *et al*.[28] They enrolled 706 Caucasian women within the middle of the gestational period. 25(OH)D concentrations were measured using immunoassay and tandem mass spectrometry. VD concentrations are classified as less than 19 ng/mL, 19–23 ng/mL, 24–28 ng/mL, more than 28 ng/mL, and normal concentration was 20–50 ng/mL. Three days following delivery, PP's mood disturbance was assessed using EPDS, which includes worrying, dejection, variation in mood, weeping, appetite variations, and sleep irregularities. Every item was given a 4-point scale ranging from 0 to 3 indicating a mood disturbance. The results of this study showed that the lowest quartile VD levels were significantly correlated to increased PPD symptoms ($p = 0.017$), while no significant association between the highest quartile VD and increased PPD symptoms.

Another community cohort study was carried out by Gur *et al*.[44] in Turkey that examined 179 pregnant mothers in mid-pregnancy (between 24 and 28 weeks gestation). The study enrolled married women who planned to get pregnant, women with a body mass index of 20–30 kg/m^2, women with an educational level of 8 years minimum, and an income greater than or equal to $4500 per year, which were aged between 18 and 40 years. This study excluded women with high-risk PPD, including any previous depression, depression in pregnancy and anxiety, stressful life, undesired pregnancy, inadequate marriage relations and inadequate social care, low socioeconomic status,

Table 1: Association between vitamin D level during pregnancy and postpartum depression between 2012 and 2022

Study, year, design, country	Sample number and collection time	Vitamin D measuring (mean) method and grouping	PPD(*) assessment	Results
Nielsen, 2013,[43] case-control, Denmark	605 cases: 875 control (serum obtained at week 25 of pregnancy)	Method: Liquid chromatography-tandem mass spectrometry groups: 6 levels (<6 ng/mL, 6–9.6 ng/mL, 10–19.6 ng/mL, 20–31.7 ng/mL, 32–39.7 ng/mL, ≥40 ng/mL)	DNBC(**)/1 year postpartum	No correlation between decreased gestational vitamin D levels and the incidence of PPD (p=0.08) and a high risk of PPD at a high level of vitamin D
Robinson, 2014,[28] prospective cohort, Australia	706 cases: Blood samples were obtained in the middle of the gestational period (18 weeks)	Method: Enzyme immunoassay kit and isotope-dilution liquid chromatography-tandem mass spectrometry groups: Four quartiles <19 ng/mL, 19–23 ng/mL, 24–28 ng/mL, >28 ng/mL	EPDS(***)/3 days after delivery	Significant relation between the lower level of vitamin D (women in the west quartile) and increased PPD symptoms (p=0.017), and no significant correlation between higher levels of vitamin D (women in the highest quartile) and increased PPD symptoms
Gur. 2014,[44] cohort, Turkey	179 cases: Blood samples were obtained in the middle of pregnancy (between 24 and 28 weeks of gestation)	Method: Enzyme-linked immunosorbent assay (ELISA) groups: <10 ng/mL (severely deficient), 20 ng/mL (mildly deficient), and >20 ng/mL (sufficient)	EPDS/1 week, 6 weeks, and 6 months after delivery	VDD(****) can be related to increases in the risk of PPD symptoms in the 1 week, 6 weeks, and 6 months after delivery (p=0.003, 0.004, and <0.001, respectively)
Accortt, 2016,[45] prospective cohort, USA	91 cases: Blood samples were obtained in the first trimester	Method: competitive chemiluminescence immunoassay platform	EPDS/4–6 weeks postpartum	An inverse association between prenatal log 25(OH)D and PPD symptomatology (β=−0.209, p=0.058)
Lamb, 2018[46] longitudinal, cohort, USA (Southern California)	125 cases: Blood samples were obtained at 3 different times, Time 1 (T1) early in gestation (mean=14 weeks), Time 2 (T2) in the third trimester (mean=32 weeks), and Time 3 (T3) at 6 weeks postpartum	Method: 25(OH)D concentrations were measured using liquid chromatography-mass spectrometry	EPDS/12–14 weeks of pregnancy, 32 weeks of pregnancy, and at 10 weeks after delivery with PPD=EPDS ≥10	Significant inverse association between depressive symptoms and vitamin concentrations (T1= −0.18, p=0.024; T2=−0.27,p=0.009; T3 = −0.22, p=0.019)
Accortt, 2021,[2] prospective cohort, USA (Los Angeles)	89 cases: Blood samples were obtained in the second trimester (18–20 weeks gestation)	Plasma vitamin D metabolite ratio (VMR)(*****) was measured by coupling reverse-phase liquid chromatography and mass spectrometry (LC-MS/MS).	(CES-D)($)/6–10 weeks postpartum	A significant relationship between PPD risk and lower VMR (p=0.007)
King, 2022,[47] prospective cohort, South Carolina (USA)	105 cases: Blood samples were obtained at four different times, weeks 8–12 of pregnancy, weeks 24–28 of pregnancy, 6–8 weeks after delivery and 10–12 weeks after delivery	Method: plasma vitamin D levels were measured by radioimmunoassay	EPDS	Women with vitamin D deficiency may have EPDS scores more than or equal to 10, but without statistical significance (OR: 2.40; 95% CI 0.92–6.27)

*Postpartum depression (PPD).**Danish Register of Medicinal Product Statistics (DNBC). ***Edinburgh Postnatal Depression Scale (EDPS).

****Vitamin D deficiency (VDD).*****Vitamin D metabolite ratio (VMR). $Center for Epidemiologic Studies Depression (CES-D)

overweight, smoking, alcohol, and several pregnancies. This study excluded the women after delivery who had intrauterine death of the fetus, neonatal infant demise, newborn with the anomaly, infant brought to neonatal critical care unit, and difficult delivery. Blood samples were drawn in mid-pregnancy (24–28 weeks), and an enzyme-linked immunosorbent assay was used for VD determination. VD classified: Less than 10 ng/mL as severely deficient, 20 ng/mL as mildly deficient, and more than 20 ng/mL as sufficient. PPD was scored *via* the EPDS system 1 week after delivery, 6 weeks following delivery, and 6 months following delivery. If the mother's score on the EPDS scoring system is ≥12, then listed as PPD. They demonstrated that VDD is associated with increased PPD risk in the 1 week, 6 weeks, and 6 months following delivery (p = 0.003, 0.004, and <0.001; respectively).

Another prospective study in the USA was performed by Accortt *et al*.,[45] who enrolled 91 African women to

evaluate the relationship between low VD with prenatal PPD symptoms. VD concentration was measured *via* a competitive chemiluminescence immunoassay in the first trimester. The symptoms of PPD were determined by the EPDS questionnaire 4–6 weeks PP. Accortt *et al*.[45] found a negative association between prenatal log 25(OH)D and PPD symptoms.

A longitudinal cohort study was carried out by Lamb *et al*.[46] and enrolled 125 women from Southern California. Study eligibility criteria included women with a minimum of 18 years old with gestational age less than 25 weeks and getting maternal care at the medical centers. Mothers with parathyroid illness or any serious psychological illness besides depression were excluded. Blood samples were obtained at three different times; Time 1 (T1) early in gestation (mean = 14 weeks), Time 2 (T2) in the third trimester (mean = 32 weeks), and Time 3 (T3) at 6 weeks PP. Measuring of 25(OH)D levels was performed using liquid mass spectrometry and PPD symptoms were evaluated using the EPDS during 12–14 weeks of pregnancy, around 32 weeks of pregnancy, and 10 weeks after delivery with EPDS ≥10. An opposite association was found between VD level and PPD symptoms. They also showed that VD may be a significant biomarker for depressed pregnant and PP women.

Another prospective cohort study was carried out in the USA by Accortt *et al*.,[2] 89 women were enrolled according to the following criteria: Gave birth to live babies, speak English or Spanish, the mother is pregnant with a single fetus inside her uterus, and were less than 20 weeks gestation. VD level was determined in the second trimester (18–20 weeks gestation), and plasma vitamin D metabolite ratio (VMR) was determined by $24,25(OH)_2/25(OH)D$. PPD symptoms were evaluated at 6–10 weeks PP using the Center for Epidemiologic Studies Depression Scale (CES-D) with ≥16 representing the risk for PPD. The range of CES-D scores is 0–60, with more symptoms at the higher scores. This study found that 34% of the participants were at risk for PPD and demonstrated that lower prenatal VD levels can predict PPD risk.

Finally, a prospective cohort study carried out by King *et al*.,[47] enrolled 105 women and excluded women with less than 18 years old, over 12 weeks of pregnancy, or not being able to provide informed consent. Blood samples were drawn at four different times; weeks 8–12 of pregnancy, weeks 24–28 of pregnancy, 6–8 weeks after delivery, and 10–12 weeks after delivery, and plasma VD levels were measured by radioimmunoassay. PPD symptoms were assessed by EPDS, with scores more or equal to 12 mean presences of depressive symptoms, and scores more or equal to 10 mean presence of minor depressive symptoms need more medical observations. Results showed deficient VD levels were associated with higher depression risk at the follow-up evaluation.

There is biological evidence for the association of VD and depression development, but more studies are needed to support the scarce literature that links VD level and depression outside of the prenatal period.[4,8,11,12] Longitudinal follow-up studies are needed to evaluate the impact of pre-postnatal VD level and PPD on both mother and infant health at different seasons, among different ethnic populations and among different socioeconomic groups.

Discussion

This study reviewed previous studies concerning the association between 25(OH)D and VD levels during pregnancy and PPD development. Many studies showed the relationship between VD levels and depression development,[4] VD and PPD during pregnancy.[36] The association between 25(OH)D concentration and depression risk may be explained by the influence of VD on the hypothalamic-pituitary-adrenal axis and excessive activity of the sympatho-adrenal system.[8,36] This may be due to the distribution of VDR in the brain. In addition, an abrupt decline in estrogen levels occurring after delivery may alter gonadotropin-releasing hormone (GnRH) by the hypophyseal portal system and thus influence neuronal activity and PPD.[4,8] Another justification may be related to the VD impact on the hemostat the calcium level in tissue and its effect on the prevention of PPD.[48] This review discussed seven publications that studied the association between gestational VD levels and PPD [Table 1].

According to this study, observational studies may be inadequate and inconclusive, regarding the association between serum VD level and PPD,[2,28,44,45,46] while other studies showed a non-significant association or no association.[43,45] Multiple methodological variations among different studies including insufficiency of a confounders' adjustment especially season, which is the main element that affects VD concentration.[11] In addition, measuring serum VD at different intervals gestational intervals. Also, variations may be due to differences in the study group population, differences in social status, ignoring the PP medical care in some studies, and self-reporting methods used to assess depression in some cases.[47] So, studies are needed to determine the correlation between PPD and pregnant VD status among different groups with larger sample sizes.

Many studies were performed that evaluate the role of VDD measured after delivery and a probable PPD threat. A case-control study enrolled 60 women from Iran by Abedi *et al*.,[17] evaluated the relationship between low VD levels and PPD postnatally. They demonstrated a significant association between VD level and PPD postnatally. Another study by Pillai *et al*.,[13] evaluated the same relationship postnatally by EPDS; that were measured at 6 weeks PP. They showed a strong relationship between low-level bioavailable 25(OH)D and the risk of PPD postnatally.

Results of these studies showed that serum VD was significantly lower in women with PPD, and severe VDD were twice more likely to have PPD.[17] Consequently, health policymakers have to pay attention to the VD level among pregnant women to be treated.

Although there is strong support for the role of VD potential in depression development, more studies are needed to examine the role of VD in the pathophysiology, prevention, and treatment of PPD. VD supplement is available and inexpensive, and it is recommended for pregnant women, to significantly decrease PPD symptoms.[49] Nevertheless, more studies are required to understand the relationship between VD level, depression development and remission postnatally.

In the PP period, self-care is usually ignored by mothers and can be a critical psychological component, which influences the well-being of mothers and infants. So, screening VD levels among pre-postnatal mothers may be essential in numerous awareness programs that can be implemented to promote psychological health. These actions can prevent psychological problems that support good quality of life.

Limitations of the study include small sample size, socioeconomic status, and inadequate information about the seasonal variation that affects VD concentration. In addition, differences in methods used for serum VD measurement at different gestational intervals with ignorance of differences among different prenatal caring systems.[46] In addition, assessing depression by self-reporting methods and cultural-ethnic variation. Studies with larger sample sizes and a range of socioeconomic situations ought to be included, for these reasons. Studies show the association between VD levels during various phases of pregnancy and the PP period are also needed. Studies about the role of early intervention, monitoring, and VD supplements in the development of PPD are also important for decoding VD in PPD at the molecular level.

Conclusion

Although there are complex associations between VD levels during pregnancy and the risk for PPD, this review showed a significant association between low VD levels and PPD development. Health policymakers must pay attention to measuring VD levels among pregnant women and recommend vitamin supplements during pregnancy to decrease PPD.

Acknowledgments

I would like to acknowledge Hashemite University for its Continuous Staff Support.

Financial support and sponsorship

Nil.

Conflicts of interest

Nothing to declare.

References

1. Fallah M, Askari G, Asami Z. Is vitamin D status associated with depression, anxiety and sleep quality in pregnancy: A systematic review. Adv Biomed Res 2020;9:32.
2. Accortt EE, Arora C, Mirocha J, Jackman S, Liang R, Karumanchi SA, *et al*. Low prenatal vitamin D metabolite ratio and subsequent postpartum depression risk. J Womens Health (Larchmt) 2021;30:113-20.
3. Nielsen NO, Strøm M, Boyd HA, Andersen EW, Wohlfahrt J, Lundqvist M, *et al*. Vitamin D status during pregnancy and the risk of subsequent postpartum depression: A case-control study PLoS One 2013;8:e80686.
4. Ribamar A, Almeida B, Soares A, Peniche B, Jesus P, Cruz SPD, *et al*. Relationship between vitamin D deficiency and both gestational and postpartum depression. Nutr Hosp 2020;37:1238-45.
5. Szpunar MJ. Association of antepartum vitamin D deficiency with postpartum depression: A clinical perspective. Public Health Nutr 2020;23:1173-8.
6. 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.
7. Amini S, Jafarirad S, Amani R. Postpartum depression and vitamin D: A systematic review. Crit Rev Food Sci Nutr 2019;59:1514-20.
8. 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;298:1045-59.
9. Alshikh Ahmad H, Alkhatib A, Luo J. Prevalence and risk factors of postpartum depression in the Middle East: A systematic review and meta-analysis. BMC Pregnancy Childbirth 2021;21:542.
10. Schiller CE, Meltzer-Brody S, Rubinow DR. The role of reproductive hormones in postpartum depression. CNS Spectr 2015;20:48-59.
11. Gould JF, Gibson RA, Green TJ, Makrides M. A systematic review of vitamin D during pregnancy and postnatally and symptoms of depression in the antenatal and postpartum period from randomized controlled trials and observational studies. Nutrients 2022;14:2300.
12. Fu CW, Liu JT, Tu WJ, Yang JQ, Cao Y. Association between serum 25-hydroxyvitamin D levels measured 24 hours after delivery and postpartum depression. BJOG 2015;122:1688-94.
13. Pillai RR, Premkumar NR, Kattimani S, Sagili H, Wilson AB, Sharon L, *et al*. Reduced maternal serum total, free and bioavailable vitamin D levels and its association with the risk for postpartum depressive symptoms. Arch Med Res 2021;52:84-92.
14. Gastaldon C, Solmi M, Correll CU, Barbui C, Schoretsanitis G. 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 2022;221:591-602.
15. Falana SD, Carrington JM. Postpartum depression: Are you listening? Nurs Clin North Am 2019;54:561-7.
16. Gur EB, Genc M, Eskicioglu F, Kurtulmus S, Guclu S. The effect of vitamin D level in pregnancy on postpartum depression. Arch Womens Ment Health 2015;18:263-4.
17. Abedi P, Bovayri M, Fakhri A, Jahanfar S. The relationship

between vitamin D and postpartum depression in reproductive-aged Iranian women. J Med Life 2018;11:286-92.
18. Trujillo J, Vieira MC, Lepsch J, Rebelo F, Poston L, Pasupathy D, *et al*. A systematic review of the associations between maternal nutritional biomarkers and depression and/or anxiety during pregnancy and postpartum. J Affect Disord 2018;232:185-203.
19. Ellsworth-Bowers ER, Corwin EJ. Nutrition and the psychoneuroimmunology of postpartum depression. Nutr Res Rev 2012;25:180-92.
20. Pearlstein T, Howard M, Salisbury A, Zlotnick C. Postpartum depression. Am J Obstet Gynecol 2009;200:357-64.
21. Yim IS, Tanner Stapleton LR, Guardino CM, Hahn-Holbrook J, Dunkel Schetter C. Biological and psychosocial predictors of postpartum depression: Systematic review and call for integration. Annu Rev Clin Psychol 2015;11:99-137.
22. Anglin RE, Samaan Z, Walter SD, McDonald SD. Vitamin D deficiency and depression in adults: Systematic review and meta-analysis. Br J Psychiatry 2013;202:100-7.
23. Shapiro GD, Fraser WD, Séguin JR. Emerging risk factors for postpartum depression: Serotonin transporter genotype and omega-3 fatty acid status. Can J Psychiatry 2012;57:704-12.
24. Boulkrane MS, Fedotova J, Kolodyaznaya V, Micale V, Drago F, van den Tol AJM, *et al*. Vitamin D and depression in women: A mini review. Curr Neuropharmacol 2020;18:288-300.
25. Kim YK, Na KS, Myint AM, Leonard BE. The role of pro-inflammatory cytokines in neuroinflammation, neurogenesis and the neuroendocrine system in major depression. Prog Neuropsychopharmacol Biol Psychiatry 2016;64:277-84.
26. Helde-Frankling M, Björkhem-Bergman L. Vitamin D in pain management. Int J Mol Sci 2017;18:2170.
27. Pfotenhauer KM, Shubrook JH. Vitamin D deficiency, its role in health and disease, and current supplementation recommendations. J Am Osteopath Assoc 2017;117:301-5.
28. Robinson M, Whitehouse AJ, Newnham JP, Gorman S, Jacoby P, Holt BJ, *et al*. Low maternal serum vitamin D during pregnancy and the risk for postpartum depression symptoms. Arch Womens Ment Health 2014;17:213-9.
29. Mahmood I, Owens CT, Hoover RM. Association between vitamin D levels during pregnancy and postpartum depression. J Pharm Technol 2015;31:223-7.
30. Bizzaro G, Antico A, Fortunato A, Bizzaro N. Vitamin D and autoimmune diseases: Is Vitamin D Receptor (VDR) polymorphism the culprit? Isr Med Assoc J 2017;19:438-43.
31. Christesen HT, Falkenberg T, Lamont RF, Jørgensen JS. The impact of vitamin D on pregnancy: A systematic review. Acta Obstet Gynecol Scand 2012;91:1357-67.
32. Föcker M, Antel J, Grasemann C, Führer D, Timmesfeld N, Öztürk D, *et al*. Effect of an vitamin D deficiency on depressive symptoms in child and adolescent psychiatric patients-A randomized controlled trial: Study protocol. BMC Psychiatry 2018;18:57.
33. van der Pligt P, Willcox J, Szymlek-Gay EA, Murray E, Worsley A, Daly RM. Associations of maternal vitamin D deficiency with pregnancy and neonatal complications in developing countries: A systematic review. Nutrients 2018;10:640.
34. Föcker M, Antel J, Grasemann C, Führer D, Timmesfeld N, Öztürk D, *et al*. Effect of a vitamin D deficiency on depressive symptoms in child and adolescent psychiatric patients-A randomized controlled trial: Study protocol. BMC Psychiatry 2018;18:57.
35. Jani R, Knight-Agarwal CR, Bloom M, Takito MY. The association between pre-pregnancy body mass index, perinatal depression and maternal vitamin D status: Findings from an Australian cohort study. Int J Womens Health 2020;12:213-9.
36. Aghajafari F, Letourneau N, Mahinpey N, Cosic N, Giesbrecht G. Vitamin D deficiency and antenatal and postpartum depression: A systematic review. Nutrients 2018;10:478.
37. Kamalzadeh L, Saghafi M, Mortazavi SS, Jolfaei AG. Vitamin D deficiency and depression in obese adults: A comparative observational study. BMC Psychiatry 2021;21:599.
38. Roy NM, Al-Harthi L, Sampat N, Al-Mujaini R, Mahadevan S, Al Adawi S, *et al*. Impact of vitamin D on neurocognitive function in dementia, depression, schizophrenia and ADHD. Front Biosci (Landmark Ed) 2021;26:566-611.
39. Bersani FS, Ghezzi F, Maraone A, Vicinanza R, Cavaggioni G, Biondi M, *et al*. The relationship between Vitamin D and depressive disorders. Riv Psichiatr 2019;54:229-34.
40. Huang JY, Arnold D, Qiu CF, Miller RS, Williams MA, Enquobahrie DA. Association of serum vitamin D with symptoms of depression and anxiety in early pregnancy. J Womens Health (Larchmt) 2014;23:588-95.
41. Guidotti A, Auta J, Chen Y, Davis JM, Dong E, Gavin DP, *et al*. Epigenetic GABAergic targets in schizophrenia and bipolar disorder. Neuropharmacology 2011;60:1007-16.
42. Kaviani M, Nikooyeh B, Zand H, Yaghmaei P, Neyestani TR. Effects of vitamin D supplementation on depression and some involved neurotransmitters. J Affect Disord 2020;269:28-35.
43. Nielsen NO, Strøm M, Boyd HA, Andersen EW, Wohlfahrt J, Lundqvist M, *et al*. Vitamin D status during pregnancy and the risk of subsequent postpartum depression: A case-control study. PLoS One 2013;8:e80686.
44. Gur EB, Gokduman A, Turan GA, Tatar S, Hepyilmaz I, Zengin EB, *et al*. Mid-pregnancy vitamin D levels and postpartum depression. Eur J Obstet Gynecol Reprod Biol 2014;179:110-6.
45. Accortt EE, Schetter CD, Peters RM, Cassidy-Bushrow AE. Lower prenatal vitamin D status and postpartum depressive symptomatology in African American women: Preliminary evidence for moderation by inflammatory cytokines. Arch Womens Ment Health 2016;19:373-83.
46. Lamb AR, Lutenbacher M, Wallston KA, Pepkowitz SH, Holmquist B, Hobel CJ. Vitamin D deficiency and depressive symptoms in the perinatal period. Arch Womens Ment Health 2018;21:745-55.
47. King CE, Wilkerson A, Newman R, Wagner CL, Guille C. Sleep, anxiety, and vitamin D status and risk for peripartum depression. Reprod Sci 2022;29:1851-8.
48. Marian J, Conn PM. Gonadotropin releasing hormone stimulation of cultured pituitary cells requires calcium. Mol Pharmacol 1979;16:196-201.
49. Vellekkatt F, Menon V. Efficacy of vitamin D supplementation in major depression: A meta-analysis of randomized controlled trials. J Postgrad Med 2019;65:74-80.