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Perinatal Weight and Risk of Prenatal and Postpartum Depressive Symptoms

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Abstract

Purpose—Pre-pregnancy obesity and weight changes accompanying pregnancy (gestational weight gain and postpartum weight retention) may be associated with risk of maternal depressive symptoms during pregnancy and in the postpartum. The few studies that have examined these relationships report conflicting findings.

Methods—We studied pregnant (n=2112) and postpartum (n=1686) women enrolled in Project Viva. We used self-reported pre-pregnancy and postpartum weight and measured prenatal weight to calculate pre-pregnancy body mass index (BMI), gestational weight gain (GWG), and postpartum weight retention (PPWR) at 6 months after birth. We assessed elevated depressive symptoms (EDS) with the Edinburgh Postnatal Depression Scale (≥ 13 on 0–30 scale) at mid-pregnancy and 6 months postpartum. We used logistic regression to estimate the odds of prenatal and postpartum EDS in relation to pre-pregnancy BMI, GWG, and PPWR.

Results—214 (10%) participants experienced prenatal EDS, and 151 (9%) postpartum EDS. Neither pre-pregnancy BMI nor GWG were associated with prenatal EDS. Pre-pregnancy obesity (BMI≥30 kg/m^2) was associated with higher odds of postpartum EDS (OR=1.69, 95% CI: 1.01,

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2.83) compared to normal pre-pregnancy weight in a model adjusted for age, race/ethnicity, nativity, education, marital status, household income, parity, pregnancy intention, and smoking.

Conclusions—Pre-pregnancy obesity is associated with elevated depressive symptoms in the postpartum period. Given the current obesity epidemic in the US and the consequences of perinatal depression, additional depression screening in this population may be warranted.

Keywords

pre-pregnancy BMI; gestational weight gain; postpartum weight retention; prenatal depression; postpartum depression

INTRODUCTION

Depression is characterized by low mood, an inability to experience pleasure, and a range of other possible symptoms, including appetite change, sleep disturbance, fatigue, guilt, diminished concentration, and recurrent ideas of self harm (1). Perinatal depression, with a period prevalence of 18% for prenatal depression and 14% for postpartum depression (2), is one of the most common complications of the perinatal period. Prenatal depression is associated with premature delivery and lower rates of breastfeeding initiation (3). Postpartum depression may impair caregiving and mother-infant interactions, with life-long cognitive and emotional repercussions for the child, including poorer language and IQ development (4). Elevated depressive symptoms in the postpartum period, regardless of if the threshold for clinical diagnosis of depression is met, negatively affects mother-infant interactions (45, 46). Understanding risk factors for perinatal depressive symptoms, particularly those that are modifiable, could advance our ability to identify women at risk and provide additional avenues for possible prevention and intervention.

Numerous studies suggest that obesity is a risk factor for depression and elevated depressive symptoms in non-pregnant populations (5–8) however, little is known about the relation between weight and depressive symptoms in the perinatal period. Maternal obesity prior to pregnancy coupled with rapid weight gain during pregnancy or excessive weight retention following pregnancy may exacerbate mood disorders through negative effects on body image and self-esteem (8, 9), or through inflammatory pathways or hypothalamic-pituitary-adrenal (HPA) axis dysregulation (6). In particular, HPA axis dysregulation is implicated in both obesity and depression (10, 11) and it has been suggested that the dysregulation of the HPA axis is a critical piece in the shared biology of these disorders (11). Generally, in obese individuals, HPA axis over-activity is observed along with elevated cortisol levels (12, 13). HPA axis dysregulation associated with major depressive disorder includes heightened cortisol levels (14), though the HPA axis dysregulation in postpartum depression may differ or even change over the course of the postpartum period (15). During pregnancy, the HPA axis undergoes substantial changes and seems to not return to pre-pregnancy functioning for months after parturition (15). Though not thoroughly understood, it appears that HPA axis dysregulation is involved in postpartum depression (15, 16).

Few studies have examined the associations between weight and weight changes with perinatal depression or depressive symptoms. Only three studies have examined the

association between pre-pregnancy weight and prenatal depression, with positive (17), null (18), and inverse (19) findings reported. When evaluating postpartum depression, there is some evidence that pre-pregnancy overweight or obesity may confer elevated risk of postpartum depressive symptoms (18, 20, 21), but other studies do not confirm this association (22, 23). Only one study has included both pre-pregnancy weight and weight gain during pregnancy (both retrospectively reported up to 6 months after birth), finding that only among obese women, lower weight gain predicted higher postpartum depressive symptoms (22). Perinatal weight changes may have different effects on mood depending on pre-pregnancy weight, but this has been largely unstudied.

Previously published studies evaluating body weight along with depression during and after pregnancy have several limitations, such as small sample sizes, inability to control for a range of confounding factors, and lack of adequate measures for perinatal depressive symptoms. To our knowledge, no study has examined weight at several time points across the perinatal period (i.e. pre-pregnancy weight, gestational weight gain, and postpartum weight retention) along with both prenatal and postpartum depressive symptoms.

Thus, we sought to evaluate the complex associations between body weight and depressive symptoms during the perinatal period in a large cohort with information about many potential confounding factors and using a validated tool for assessing depressive symptoms in pregnancy and postpartum. Our objectives were to (a) evaluate the associations of pre-pregnancy body mass index (BMI) and gestational weight gain (GWG) with elevated depressive symptoms (EDS) during pregnancy and (b) evaluate the associations of pre-pregnancy BMI, GWG, and postpartum weight retention (PPWR) with EDS in the postpartum period.

METHODS

Sample and data collection

Subjects were from Project Viva, a prospective cohort study of pregnant women and their singleton children. Between 1999 and 2002, women were recruited to participate in Project Viva during their first prenatal visit to a multi-specialty group practice at eight urban and suburban obstetric offices in eastern Massachusetts (Atrius Harvard Vanguard Medical Associates). Women were eligible if they were ≤22 gestational weeks at enrollment, able to complete questionnaires and interviews in English and had a singleton pregnancy. Details about the cohort have been reported elsewhere (24). All participating women provided written informed consent. The institutional review board at Harvard Pilgrim Health Care approved the study.

Among 2,128 eligible women enrolled in Project Viva, we excluded 16 women with preexisting type 1 or type 2 diabetes, leaving 2,112 women for the analysis of prenatal depressive symptoms. Of these, 1,686 (80%) women completed 6-month postpartum follow-up questionnaires, and were included for the analysis of postpartum depressive symptoms.

Pre-pregnancy BMI, gestational weight gain, and postpartum weight retention

Mothers reported pre-pregnancy weight on questionnaires at enrollment. Among 343 women who had weight recorded in the medical record in the 3 months before their last menstrual period, the association between self-reported and clinically measured weight was linear. Correlation coefficients (r= 0.997 overall) and mean underreporting of weight (approximately 1 kg) did not differ by race/ethnicity, gestational age at study enrollment, or pre-pregnancy BMI category (25). We calculated pre-pregnancy body mass index (BMI) as self-reported pre-pregnancy weight (kilograms) divided by height (meter squared) and categorized women as underweight (<18.5 kg/m^2), normal weight (18.5–<25.0 kg/m^2), overweight (25.0–<30 kg/m^2), and obese (≥30.0 kg/m^2).

We obtained clinical pregnancy weights from medical records for all 2,112 women and calculated total gestational weight gain (GWG) as the difference between the last weight prior to delivery and the self-reported pre-pregnancy weight. We classified GWG as inadequate, adequate, or excessive, according to the 2009 Institute of Medicine's guidelines (26). We also determined gestational weight gain up to the time of the Edinburgh Postnatal Depression Scale (EPDS) assessment during pregnancy.

We calculated postpartum weight retention as measured weight at 6 months postpartum minus self-reported pre-pregnancy weight. We dichotomized postpartum weight retention as substantial (>5 kg) or not (≤5 kg). This cut point for substantial postpartum weight retention (SPPWR) predicts later obesity and its consequences (27, 28).

Depressive symptoms

We assessed depressive symptoms with the 10-item Edinburgh Postnatal Depression Scale (EPDS) in mid-pregnancy (median 27.8 weeks gestation) and at approximately 6 months after birth (median 6.3 months). We chose the EPDS because it has been validated for prenatal and postpartum use (29, 30). The EPDS uses a four-point scale (0–3) to assess the frequency of ten symptoms over the past week. Items were developed to assess depression in the postpartum period (29). Items include: the ability to laugh, looking forward to things, blaming self, anxiety, fear or panic, inability to cope, difficulty sleeping, sadness, tearfulness, and ideas of self harm. We used the standard cut-point of 13 or more (on the 0–30 point scale) to indicate elevated depressive symptoms (EDS), consistent with previous work in this cohort (31–33) and in other large cohorts that collected EPDS data prenatally and postnatally (19, 34). This cut-point indicates probable clinical depression with a sensitivity of 86% and specificity of 78% in the postnatal period (29). Finally, it should be noted that the EPDS is a screening tool that measures probable depression, and is not a clinical diagnosis of depression; thus, we refer to an EPDS score of 13 or higher as elevated depressive symptoms.

Covariates

During early pregnancy, women reported age, race/ethnicity, education, nativity, parity, marital status, household income, pregnancy intention, and smoking behavior via in-person interviews or self-administered questionnaires. At mid-pregnancy, we assessed history of depression before the index pregnancy (yes to any of these three questions: a diagnosis of

depression by a health care professional; prescribed medications for depression; ever experienced 2 weeks or more of feeling depressed, down, or little interest in pleasurable activities). From questionnaires and interviews at 6 months postpartum, we assessed maternal employment, postpartum physical symptoms (i.e. hemorrhoids, varicose veins, incontinence, sore breasts, pain with sex, back pain, or sciatica), household financial difficulties, and duration of breastfeeding.

Statistical analysis

We calculated bivariate statistics by pre-pregnancy BMI category using means and standard deviations (SD) for continuous variables and percentages for categorical variables. We used multivariable logistic regression to calculate odds ratios (OR) and 95% confidence intervals (95% CI) for the associations between perinatal weight and elevated depressive symptoms (EDS).

For predicting prenatal EDS, we present two models (age-adjusted and multivariable adjusted) for both maternal BMI and for GWG up until depression screening. We selected covariates as factors that have previously been associated with weight or depressive symptoms: maternal age, race/ethnicity, nativity, parity, education, marital status, household income, pregnancy intention, smoking behavior (all as described in Table 1). In preliminary analyses, we examined the GWG up until depression screening - prenatal EDS relationship for non-linearity or places where categories might be introduced. Finding none, we assume linearity adequately describes the relationship between GWG up until mid-pregnancy depression screening and the odds of prenatal EDS.

For predicting postpartum EDS, we present results from 4 different models, each with a different exposure: pre-pregnancy BMI categories, GWG categories, SPPWR, and the interaction between BMI and SPPWR. Similar to analyses predicting prenatal EDS, we present an age-adjusted model and a multivariable model adjusted for prenatal factors. When SPPWR is the sole exposure, we present a third model that additionally adjusts for postpartum factors assessed at 6 months postpartum: maternal employment, breastfeeding, postpartum physical conditions, and financial hardship. Because of small numbers in the category, we excluded women who were underweight for the analysis of the interaction between BMI category and SPPWR.

As sensitivity analyses, we evaluated history of depression as an effect modifier for both prenatal and postpartum depressive symptoms. In additional sensitivity analyses, we used multivariable linear regression to examine both prenatal and postpartum depressive symptoms in continuous form, using log-transformed EPDS score as the outcome. In a post-hoc analysis, we examined the association between weight change from birth to 6 months postpartum with postpartum EDS.

To account for missing data, we used multiple imputation to impute missing values for all analyses. We imputed 50 datasets using the 'chained equations' method (35). We included exposures, outcomes, covariates, and potential predictors of missing values in our imputation model. We then combined information across the imputed datasets. We conducted analyses using SAS 9.3 (SAS Institute, Cary, NC).

RESULTS

Mothers in this sample were predominantly white, married, and had an annual household income over $70,000 at enrollment 1999–2002. Two hundred fourteen (10%) participants experienced prenatal EDS, and 151 (9%) experienced postpartum EDS. According to their pre-pregnancy BMI, 22% of Project Viva participants were overweight (BMI 25–29.9 kg/m^2) and 16% were obese (BMI≥30 kg/m^2). All baseline sociodemographic characteristics varied by pre-pregnancy BMI category (Table 1). 35% of women retained at least 5 kg at 6 months postpartum.

Neither pre-pregnancy BMI nor gestational weight gain up to the mid-pregnancy EPDS assessment were associated with prenatal EDS (Table 2).

Pre-pregnancy obesity was associated with higher odds of postpartum EDS. Compared to normal weight women, women who were obese before pregnancy had higher odds of experiencing postpartum EDS in age-adjusted models (OR=2.23, 95% CI: 1.38, 3.58), with some attenuation in fully adjusted models (OR=1.69, 95% CI: 1.01, 2.83) (Table 3). Women who were underweight pre-pregnancy also had suggestion of a higher odds of postpartum elevated depressive symptoms, though confidence intervals were wide (adjusted OR=1.36, 95% CI: 0.50, 3.68) (Table 3). Gestational weight gain was not associated with postpartum EDS.

There was some evidence that substantial postpartum weight retention may confer elevated risk of postpartum EDS, although confidence intervals did not exclude the null (adjusted OR=1.22, 95% CI: 0.79, 1.86) (Table 3). For the interaction between pre-pregnancy BMI and SPPWR, wide confidence intervals suggest lack of power to detect a relationship, but there was a suggestion that obese women who retain substantial weight in the postpartum period may have a higher risk of postpartum EDS compared to women with normal pre-pregnancy weight and ≤5 kg postpartum weight retention (OR=2.23, 95% CI: 1.09, 4.55) (Supplementary Table). There was no association between weight change from birth to 6 months postpartum with postpartum EDS (data not shown).

To understand if the associations between perinatal weight and perinatal depressive symptoms are different among women with different histories of depression, we performed sensitivity analyses. In models predicting prenatal EDS, estimated associations were not meaningfully different for women without a history of depression compared to women with a history of depression. For the models predicting postpartum EDS, we found estimates similar to those shown in table 3 when we, a) restricted the sample to women with no history of depression before pregnancy and no prenatal EDS and b) defined the outcome as new onset postpartum EDS, that is, postpartum EDS without prenatal EDS (data not shown).

To examine if perinatal weight was associated with incremental changes in depressive symptoms, we examined both prenatal and postpartum EPDS scores as log-transformed continuous outcomes. No association was detected between any of the exposures and the log-transformed linear outcomes of prenatal and postpartum EPDS score (results not shown).

DISCUSSION

In this study, we found a prospective association between pre-pregnancy obesity and elevated depressive symptoms at 6 months postpartum. We did not find a strong association between perinatal weight and prenatal depressive symptoms. That results were largely the same in our sensitivity analyses restricted to women without a history of depression (pre-pregnancy and during pregnancy) suggests that the association between pre-pregnancy weight and postpartum depressive symptoms is not necessarily due to a bi-directional or causal chain between depression and weight gain that starts earlier in life. As such, obese women, regardless of depression history, may be at elevated risk of postpartum depression.

Our finding that pre-pregnancy obesity is associated with risk of postpartum depressive symptoms is consistent with other research (18, 20, 21) and suggest a possible target population for postpartum follow-up and/or intervention to reduce the burden of depressive symptoms.

We did not observe an association of either pre-pregnancy weight or early pregnancy GWG with prenatal depressive symptoms. Of the three prior studies that have explicitly examined these associations, one found a positive association between pre-pregnancy obesity and likelihood of major depressive disorder across pregnancy (17), one found no association between pre-pregnancy BMI and depressive symptoms in pregnancy (18), and one found that pre-pregnancy overweight (but not obesity) was associated with lower odds of elevated depressive symptoms across pregnancy (19). A 2014 review of perinatal weight and mental disorders (36) examined published studies with enough information to extract data for the association between pre-pregnancy weight and depression during pregnancy; that is, there are only a handful of published studies examining this association directly, but many others present adequate data to examine a bivariate association between pre-pregnancy weight and depression during pregnancy. Using bivariate information, the authors pooled data from 29 studies: compared to normal weight women, the unadjusted pooled odds ratio for prenatal depression for pre-pregnancy obesity was 1.43 (95% CI: 1.27, 1.61) and for pre-pregnancy overweight was OR=1.19 (95% CI: 1.09, 1.31) (36). Discrepancies between findings may be explained by differences in adjustment for confounding factors, timing of and method/scale used to assess depression or depressive symptoms, and sample composition. In our analyses, household income and race/ethnicity were particularly important confounding factors. Of the other studies in this arena, only the Ertel et al study controlled for income (19). The meta-analysis (33) was not able to control for any potential confounders. Sample composition, particularly social and cultural factors, may influence body image, weight/shape satisfaction, and weight gain attitudes. For example, in a low-income sample of pregnant women in the U.S., higher weight gain was associated with depressive symptoms among European Americans, but this association did not hold for African American women (9).

Though additional research on perinatal weight and perinatal depression is required, divergent associations of weight with prenatal depressive symptoms as compared with postpartum depressive symptoms may be due to different attitudes regarding weight change during pregnancy compared to postpartum. Specifically, women may view weight and weight changes during pregnancy in a positive, or less negative way (18, 37, 38). Thus,

excess pre-pregnancy weight and weight gain during pregnancy may not contribute to prenatal depressive symptoms. In contrast, it may be that weight-related concerns return and even intensify in the postpartum period (37, 39). This may explain why pre-pregnancy weight and weight retention (though weight retention results included the null) were associated with postpartum depressive symptoms in our sample, but gestational weight gain was not.

Divergent associations with prenatal compared to postpartum depression may also be explained by distinct etiologies and pathophysiologies for prenatal compared to postpartum depression (4). For example, the HPA axis dysregulation seen in both obesity and depression may provide a common biologic link between pre-pregnancy obesity and postpartum depressive symptoms, though not with prenatal depressive symptoms. The HPA axis undergoes major changes during pregnancy, and it has been suggested that exaggeration of these changes or a slower return to normal HPA axis functioning after parturition may put women at higher risk of postpartum depression (16). Indeed, differences in HPA axis reactivity have been observed between depressed and non-depressed women at 6 months postpartum (15). Perhaps underlying HPA axis changes associated with obesity places these women at higher risk of such postpartum differences. A next step in this line of research would be to integrate measures of perinatal weight with HPA axis functioning and depressive symptoms across the perinatal period.

Strengths of the current study are that we were able to examine perinatal weight and weight change at 3 time points (i.e. pre-pregnancy, GWG, weight retention) along with depressive symptoms both during pregnancy and in the postpartum. Additionally, we were able to account for a wide range of potential confounding factors in a large, prospective cohort. Our examination of depression history allowed us to evaluate first-onset prenatal and postpartum depressive symptoms, accounting for possible recurrence of depressive symptoms and the recursive nature of weight change and depression.

Despite these strengths, this study had several limitations. First, pre-pregnancy and postpartum weight were self-reported in this study population. However, a validation study in this cohort showed very high reliability for self-reported weight when compared with clinical records (25). Second, though the EPDS is highly correlated with clinical depressive symptoms, it is a measure of depressive symptoms rather than clinical depression. As such, we can only evaluate elevated depressive symptoms and cannot determine whether these associations hold true for clinically diagnosed depression. Additionally, there may be different cut points to best distinguish high versus low depressive symptoms depending on timing of administration, as well as sociodemographic and contextual characteristics (40–43). However, among validation studies of the English version of the EPDS using the standard cut point of 13 or higher for postpartum depression, sensitivity ranged from 76 to 100% and specificity ranged from 70 to 99% (41). Future research into the interplay of perinatal weight and depressive symptoms using the EPDS may usefully examine alternate categorizations and/or functional forms for depressive symptoms. We note, however, that our examination of continuous depressive symptoms revealed that, at least in these data, depressive symptoms did not have a linear association with perinatal weight exposures. Third, though we included many potential confounding factors, there remains the possibility

that a common antecedent explains the association between pre-pregnancy obesity and postpartum depressive symptoms. In particular, future research may usefully examine how a history of trauma or abuse plays into the perinatal weight – perinatal depression relationship. Finally, it is worth noting that our study population, while somewhat diverse, is predominantly white and of higher socioeconomic status. Therefore, we did not have enough power to test effect modification based on potential racial/ethnic differences and sociocultural factors. Future studies will need to evaluate these associations in more diverse and disadvantaged study populations.

In summary, our study suggests that pre-pregnancy obesity may confer risk for elevated depressive symptoms in the postpartum period. There is evidence that screening and treatment programs for perinatal depression can be effective at reducing depressive symptoms and depression prevalence (44). Given the current obesity epidemic in the U.S. and the consequences of postpartum depression, prevention and screening efforts may usefully target obese women during pregnancy and postpartum.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

BMI	body mass index
EDS	elevated depressive symptoms
EPDS	Edinburgh Postnatal Depression Scale
GWG	gestational weight gain
HPA	hypothalamic-pituitary-adrenal
OR	odds ratio
PPWR	postpartum weight retention
SD	standard deviation
SPPWR	substantial postpartum weight retention

References

1. American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders: DSM-5. Washington, D.C.: American Psychiatric Association; 2013.
2. Gavin NI, Gaynes BN, Lohr KN, Meltzer-Brody S, Gartlehner G, Swinson T. Perinatal depression: a systematic review of prevalence and incidence. Obstet Gynecol. 2005; 106(5 Pt 1):1071–83. [PubMed: 16260528]

3. Grigoriadis S, VonderPorten EH, Mamisashvili L, Tomlinson G, Dennis CL, Koren G, et al. The impact of maternal depression during pregnancy on perinatal outcomes: a systematic review and meta-analysis. J Clin Psychiatry. 2013; 74(4):e321–41. [PubMed: 23656857]
4. O'Hara MW, McCabe JE. Postpartum depression: current status and future directions. Annu Rev Clin Psychol. 2013; 9:379–407. [PubMed: 23394227]
5. de Wit LM, van Straten A, van Herten M, Penninx BW, Cuijpers P. Depression and body mass index, a u-shaped association. BMC Public Health. 2009; 9:14. [PubMed: 19144098]
6. Luppino FS, de Wit LM, Bouvy PF, Stijnen T, Cuijpers P, Penninx BW, et al. Overweight, obesity, and depression: a systematic review and meta-analysis of longitudinal studies. Arch Gen Psychiatry. 2010; 67(3):220–9. [PubMed: 20194822]
7. Ma J, Xiao L. Obesity and depression in US women: results from the 2005–2006 National Health and Nutritional Examination Survey. Obesity (Silver Spring). 2010; 18(2):347–53. [PubMed: 19590500]
8. Silveira ML, Ertel KA, Dole N, Chasan-Taber L. The role of body image in prenatal and postpartum depression: a critical review of the literature. Arch Womens Ment Health. 2015; 18(3):409–21. [PubMed: 25895137]
9. Cameron RP, Grabill CM, Hobfoll SE, Crowther JH, Ritter C, Lavin J. Weight, self-esteem, ethnicity, and depressive symptomatology during pregnancy among inner-city women. Health Psychol. 1996; 15(4):293–7. [PubMed: 8818676]
10. Goldstein JM, Holsen L, Huang G, Hammond BD, James-Todd T, Cherkerzian S, et al. Prenatal stress-immune programming of sex differences in comorbidity of depression and obesity/ metabolic syndrome. Dialogues Clin Neurosci. 2016; 18(4):425–36. [PubMed: 28179814]
11. Bornstein SR, Schuppenies A, Wong ML, Licinio J. Approaching the shared biology of obesity and depression: the stress axis as the locus of gene-environment interactions. Mol Psychiatry. 2006; 11(10):892–902. [PubMed: 16880826]
12. Pasquali R, Vicennati V. The abdominal obesity phenotype and insulin resistance are associated with abnormalities of the hypothalamic-pituitary-adrenal axis in humans. Horm Metab Res. 2000; 32(11–12):521–5. [PubMed: 11246819]
13. Incollingo Rodriguez AC, Epel ES, White ML, Standen EC, Seckl JR, Tomiyama AJ. Hypothalamic-pituitary-adrenal axis dysregulation and cortisol activity in obesity: A systematic review. Psychoneuroendocrinology. 2015; 62:301–18. [PubMed: 26356039]
14. Plotsky PM, Owens MJ, Nemeroff CB. Psychoneuroendocrinology of depression. Hypothalamic-pituitary-adrenal axis. Psychiatr Clin North Am. 1998; 21(2):293–307. [PubMed: 9670227]
15. de Rezende MG, Garcia-Leal C, de Figueiredo FP, Cavalli Rde C, Spanghero MS, Barbieri MA, et al. Altered functioning of the HPA axis in depressed postpartum women. J Affect Disord. 2016; 193:249–56. [PubMed: 26773916]
16. Glynn LM, Davis EP, Sandman CA. New insights into the role of perinatal HPA-axis dysregulation in postpartum depression. Neuropeptides. 2013; 47(6):363–70. [PubMed: 24210135]
17. Bodnar LM, Wisner KL, Moses-Kolko E, Sit DK, Hanusa BH. Prepregnancy body mass index, gestational weight gain, and the likelihood of major depressive disorder during pregnancy. J Clin Psychiatry. 2009; 70(9):1290–6. [PubMed: 19607761]
18. Carter AS, Baker CW, Brownell KD. Body mass index, eating attitudes, and symptoms of depression and anxiety in pregnancy and the postpartum period. Psychosom Med. 2000; 62(2): 264–70. [PubMed: 10772407]
19. Ertel KA, Silveira ML, Pekow PS, Dole N, Markenson G, Chasan-Taber L. Prepregnancy body mass index, gestational weight gain, and elevated depressive symptoms in a Hispanic cohort. Health Psychol. 2015; 34(3):274–8. [PubMed: 25110848]
20. LaCoursiere DY, Barrett-Connor E, O'Hara MW, Hutton A, Varner MW. The association between prepregnancy obesity and screening positive for postpartum depression. BJOG. 2010; 117(8): 1011–8. [PubMed: 20536433]
21. Lacoursiere DY, Baksh L, Bloebaum L, Varner MW. Maternal body mass index and self-reported postpartum depressive symptoms. Matern Child Health J. 2006; 10(4):385–90. [PubMed: 16673179]

22. Cline KM, Decker J. Does weight gain during pregnancy influence postpartum depression? J Health Psychol. 2012; 17(3):333–42. [PubMed: 21824894]
23. Sundaram S, Harman JS, Peoples-Sheps MD, Hall AG, Simpson SH. Obesity and postpartum depression: does prenatal care utilization make a difference? Matern Child Health J. 2012; 16(3): 656–67. [PubMed: 21533884]
24. Oken E, Baccarelli AA, Gold DR, Kleinman KP, Litonjua AA, De Meo D, et al. Cohort profile: project viva. Int J Epidemiol. 2015; 44(1):37–48. [PubMed: 24639442]
25. Provenzano AM, Rifas-Shiman SL, Herring SJ, Rich-Edwards JW, Oken E. Associations of maternal material hardships during childhood and adulthood with prepregnancy weight, gestational weight gain, and postpartum weight retention. J Womens Health (Larchmt). 2015; 24(7):563–71. [PubMed: 25902486]
26. Rasmussen, KM., Yaktine, AL. Institute of Medicine (U.S.). Committee to Reexamine IOM Pregnancy Weight Guidelines. Weight gain during pregnancy : reexamining the guidelines. Washington, DC: National Academies Press; 2009. p. xivp. 854
27. Gunderson EP, Abrams B. Epidemiology of gestational weight gain and body weight changes after pregnancy. Epidemiol Rev. 1999; 21(2):261–75. [PubMed: 10682262]
28. Ohlin A, Rossner S. Maternal body weight development after pregnancy. Int J Obes. 1990; 14(2): 159–73.
29. Cox JL, Holden JM, Sagovsky R. Detection of postnatal depression. Development of the 10-item Edinburgh Postnatal Depression Scale. Br J Psychiatry. 1987; 150:782–6. [PubMed: 3651732]
30. Murray D, Cox JL. Screening for depression during pregnancy with the edinburgh depression scale (EDDS). Journal of Reproductive and Infant Psychology. 1990; 8(2):99–107.
31. Rich-Edwards JW, Kleinman K, Abrams A, Harlow BL, McLaughlin TJ, Joffe H, et al. Sociodemographic predictors of antenatal and postpartum depressive symptoms among women in a medical group practice. J Epidemiol Community Health. 2006; 60(3):221–7. [PubMed: 16476752]
32. Ertel KA, Koenen KC, Rich-Edwards JW, Gillman MW. Antenatal and postpartum depressive symptoms are differentially associated with early childhood weight and adiposity. Paediatr Perinat Epidemiol. 2010; 24(2):179–89. [PubMed: 20415775]
33. Ertel KA, James-Todd T, Kleinman K, Krieger N, Gillman M, Wright R, et al. Racial discrimination, response to unfair treatment, and depressive symptoms among pregnant black and African American women in the United States. Ann Epidemiol. 2012; 22(12):840–6. [PubMed: 23123506]
34. Heron J, O'Connor TG, Evans J, Golding J, Glover V, Team AS. The course of anxiety and depression through pregnancy and the postpartum in a community sample. J Affect Disord. 2004; 80(1):65–73. [PubMed: 15094259]
35. White IR, Royston P, Wood AM. Multiple imputation using chained equations: Issues and guidance for practice. Stat Med. 2011; 30(4):377–99. [PubMed: 21225900]
36. 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.
37. Baker CW, Carter AS, Cohen LR, Brownell KD. Eating attitudes and behaviors in pregnancy and postpartum: global stability versus specific transitions. Ann Behav Med. 1999; 21(2):143–8. [PubMed: 10499135]
38. Loth KA, Bauer KW, Wall M, Berge J, Neumark-Sztainer D. Body satisfaction during pregnancy. Body Image. 2011; 8(3):297–300. [PubMed: 21561821]
39. Rallis S, Skouteris H, Wertheim EH, Paxton SJ. Predictors of body image during the first year postpartum:a prospective study. Women Health. 2007; 45(1):87–104. [PubMed: 17613464]
40. Kozinszky Z, Dudas RB. Validation studies of the Edinburgh Postnatal Depression Scale for the antenatal period. J Affect Disord. 2015; 176:95–105. [PubMed: 25704562]
41. Gibson J, McKenzie-McHarg K, Shakespeare J, Price J, Gray R. A systematic review of studies validating the Edinburgh Postnatal Depression Scale in antepartum and postpartum women. Acta Psychiatr Scand. 2009; 119(5):350–64. [PubMed: 19298573]

42. King PA. Validity of postpartum depression screening across socioeconomic groups: a review of the construct and common screening tools. J Health Care Poor Underserved. 2012; 23(4):1431–56. [PubMed: 23698660]

43. Downe SM, Butler E, Hinder S. Screening tools for depressed mood after childbirth in UK-based South Asian women: a systematic review. J Adv Nurs. 2007; 57(6):565–83. [PubMed: 17346316]

44. O'Connor E, Rossom RC, Henninger M, Groom HC, Burda BU. Primary Care Screening for and Treatment of Depression in Pregnant and Postpartum Women: Evidence Report and Systematic Review for the US Preventive Services Task Force. JAMA. 2016; 315(4):388–406. [PubMed: 26813212]

45. Braarud HC, Skotheim S, Hoie K, Markhus MW, Kjellevold M, Graff IE, et al. Affective facial expression in sub-clinically depressed and non-depressed mothers during contingent and non-contingent face-to-face interactions with their infants. Infant Behav Dev. 2017; 48(Pt B):98–104. [PubMed: 28551029]

46. Behrendt HF, Konrad K, Goecke TW, Fakhrabadi R, Herpertz-Dahlmann B, Firk C. Postnatal Mother-to-Infant Attachment in Subclinically Depressed Mothers: Dyads at Risk? Psychopathology. 2016; 49(4):269–76. [PubMed: 27497959]

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Table 1

Characteristics among Project Viva participants, overall and according to category of pre-pregnancy BMI

	Pre-pregnancy BMI, kg/m^2					
	Overall	**<18.5**	**18.5–<25.0**	**25.0–<30.0**	**>=30.0**	
	n=2112	**n=81**	**n=1242**	**n=458**	**n=331**	
	% or Mean (SD)[1]					**P-values[2]**
Prenatal factors						
Age at enrollment, years	31.8 (5.2)	29.8 (6.3)	32.0 (5.1)	31.9 (5.3)	31.4 (5.3)	0.001
Race/ethnicity						<.0001
. Black	17	17	11	19	32	
. Hispanic	7	4	6	10	8	
. Asian	6	21	6	4	2	
. Other	4	4	3	6	5	
. White	66	55	73	61	53	
Education						<.0001
. High school or less	12	14	9	13	22	
. Some college	23	29	18	25	37	
. College graduate	35	23	38	35	29	
. Graduate degree	29	34	34	27	13	
Married or cohabitating						0.02
. No	9	12	7	9	12	
. Yes	91	88	93	91	88	
Annual household income						<.0001
. $5,000–40,000	19	26	14	21	32	
. $40,001–70,000	23	25	21	23	31	
. >$70,000	58	49	65	56	37	
Parous						<.0001
. No	48	54	53	42	37	
. Yes	52	46	47	58	63	
Pregnancy intention						<.0001

	Overall	Pre-pregnancy BMI, kg/m^2 <18.5	18.5–<25.0	25.0–<30.0	>=30.0	
	n=2112	n=81	n=1242	n=458	n=331	
	% or Mean (SD)[1]					P-values[2]
. Actively trying	60	47	64	58	49	
. Not trying, but glad	33	38	30	34	41	
. Not now/never	8	15	6	9	10	
Pregnancy smoking status						0.003
. Never	69	74	70	64	68	
. Former	19	12	20	21	15	
. Smoked during pregnancy	12	14	10	15	17	
Elevated Depressive Symptoms (EDS) Outcomes						
Mid-Pregnancy EDS						0.10
. No	90	86	91	88	88	
. Yes	10	14	9	12	12	
Postpartum EDS at 6 months						0.01
. No	91	89	93	91	85	
. Yes	9	11	7	9	15	
Postpartum factors						
Breast feeding duration at 6 months, months	3.9 (2.4)	3.6 (2.4)	4.2 (2.3)	3.7 (2.5)	3.1 (2.5)	<.0001
Maternal employment						0.79
. Employed, maternity leave	6	2	6	7	6	
. Not employed, looking	7	8	6	6	8	
. Not employed, not looking	24	27	26	21	22	
. Employed	64	63	62	66	64	
Financial hardship						<.0001
. No	92	90	94	91	83	
. Yes	8	10	6	9	17	
Postpartum BMI at 6 months, kg/m^2						<.0001
. <18.5	2	33	1	0	0	

	Overall	Pre-pregnancy BMI, kg/m^2 <18.5	18.5–<25.0	25.0–<30.0	>=30.0	
	n=2112	n=81	n=1242	n=458	n=331	
	% or Mean (SD)[1]					P-values[2]
. 18.5–<25.0	49	67	77	4	0	
. 25.0–<30.0	27	0	22	65	3	
. >=30.0	22	0	0	30	97	
Number of postpartum physical conditions	1.9 (1.3)	1.6 (1.3)	1.9 (1.3)	1.8 (1.3)	1.8 (1.2)	0.01

For all prenatal data n=2112; for postpartum data n=1686

[1] Based on numbers averaged across 50 imputed datasets

[2] Global p-values

BMI, body mass index
IOM, Institute of Medicine
EPDS, Edinburgh Postnatal Depression Scale

Table 2

Odds ratios and relative risks, along with 95% confidence intervals for elevated prenatal depressive symptoms according to pre-pregnancy body mass index and gestational weight gain

	Age-adjusted model[1]	Multivariable model
Pre-pregnancy BMI		
Underweight	1.51 (0.73, 3.13)	1.31 (0.62, 2.78)[2]
Normal	1.00 (Ref)	1.00 (Ref)
Overweight	1.45 (0.96, 2.18)	1.28 (0.84, 1.95)
Obese	1.45 (0.93, 2.28)	1.20 (0.74, 1.95)
Gestational weight gain up to mid-pregnancy EPDS assessment (per kg)	0.99 (0.95, 1.03)	1.00 (0.96, 1.04)[3]

[1] Adjusted for age at enrollment

[2] Adjusted for age at enrollment, race/ethnicity, nativity, education, marital status, household income, parity, pregnancy intention, and smoking

[3] Adjusted for age at enrollment, race/ethnicity, nativity, education, marital status, household income, parity, pregnancy intention, smoking, and pre-pregnancy body mass index

Table 3

Odds ratios and 95% confidence intervals for elevated postpartum depressive symptoms according to pre-pregnancy body mass index, gestational weight gain and postpartum weight retention

	Age-adjusted model[1]	Multivariable model	Multivariable + postpartum factors
Pre-pregnancy BMI			
Underweight	1.37 (0.52, 3.61)	1.36 (0.50, 3.68)[2]	--
Normal	1.00 (Ref)	1.00 (Ref)	--
Overweight	1.19 (0.74, 1.91)	1.05 (0.64, 1.70)	--
Obese	2.23 (1.38, 3.58)	1.69 (1.01, 2.83)	--
Gestational weight gain			
Inadequate	1.10 (0.61, 2.01)	0.98 (0.53, 1.82)[3]	--
Adequate	1.00 (Ref)	1.00 (Ref)	--
Excessive	1.07 (0.70, 1.64)	0.96 (0.62, 1.50)	--
Postpartum weight retention			
≤5 kg	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
>5 kg	1.43 (0.95, 2.14)	1.22 (0.79, 1.86)[3]	1.23 (0.80, 1.90)[4]

[1] Adjusted for age at enrollment

[2] Adjusted for age at enrollment, race/ethnicity, nativity, education, marital status, household income, parity, pregnancy intention, and smoking

[3] Adjusted for age at enrollment, race/ethnicity, nativity, education, marital status, household income, parity, pregnancy intention, smoking, and pre-pregnancy body mass index

[4] Adjusted for age at enrollment, race/ethnicity, nativity, education, marital status, household income, parity, pregnancy intention, smoking, and pre-pregnancy body mass index, plus postpartum maternal employment, duration of breastfeeding, financial hardship, and postpartum physical symptoms