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A prospective study of maternal anxiety, perceived stress, and depressive symptoms in relation to infant cognitive development

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Abstract

Aim—Our objective was to examine the associations between maternal psychological health (trait anxiety, perceived stress, depressive symptoms) during pregnancy or postpartum and infant visual, language, motor, and overall cognitive development.

Study Design and Methods—In the prospective Pregnancy, Infection, and Nutrition Study (2001–2006), central North Carolina women completed self-administered questionnaires during pregnancy to assess trait anxiety and depressive symptoms. An in-person interview assessed maternal perceived stress and depressive symptoms in the 4th postpartum month. Infant development was assessed at 12 months using the Mullen Scales of Early Learning (n=358). Multiple linear regression with restricted cubic splines was used to examine potential non-linear associations between trait anxiety, perceived stress, and depressive symptoms in relation to Mullen sub-scales and Composite scores.

Results—Increasing maternal anxiety was associated with poorer overall cognition (adjusted β for Composite=−0.2, 95% CI: −0.4, 0.0). Postpartum stress was positively associated with language development and general cognition (adjusted β for Expressive Language=0.2, 95% CI: 0.0, 0.4; adjusted β for Composite=0.3, 95% CI: 0.0, 0.6). Elevated depressive symptoms throughout pregnancy and postpartum were associated with better fine motor skills (adjusted

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β=9.7, 95% CI: 3.9, 15.5). Anxiety, postpartum depressive symptoms and stress were associated with gross motor skills in a non-linear fashion, as were postpartum depressive symptoms and stress with expressive language.

Conclusions—Maternal trait anxiety, depressive symptoms and stress had little negative influence on infant cognitive development. In fact, moderate psychosocial distress may slightly accelerate motor development in particular, and some aspects of language.

INTRODUCTION

Infancy is a period of rapid cognitive development, and the early psychosocial environment of the child plays a role in mental and emotional health across the lifespan. Maternal anxiety, stress, and depression are common psychosocial influences of concern for child development. Pregnancy and new motherhood may be particularly stressful periods for women, with postpartum depression affecting up to 19% of mothers (1).

Mothers who experience significant anxiety, stress, or depression may provide a less stimulating environment for their child's development at least in part because they may react inappropriately to their children's cues (2). Numerous studies have observed an association between maternal postpartum or chronic depressive symptoms and poorer child performance on cognitive and behavioral assessments (3–6). Other studies noted that greater maternal stress and anxiety interfere with mother-child interaction, with negative consequences for infant temperament and cognition (7–9). Recent research has also identified a potential fetal programming effect of antenatal anxiety (10,11). A few studies have suggested that the association between stress during pregnancy and child cognition may be non-linear, with children exposed to moderate stress performing as well as or better than children exposed to low levels of stress, especially in samples with relatively high socioeconomic status (12,13). Few studies have reported effects of maternal depressed mood on child development as early as infancy, and those results have been inconsistent (10,14–16). Variability across studies could be due to variation in the timing and methods of assessing maternal psychological health and child development, insufficient power to detect small effects, and varying ability to control for key confounders. Some areas of development may be more affected than others, although it remains unclear which developmental domains are most at risk given the varying results across and within studies. Thus, separately evaluating language, visual reception, and motor skills could provide more detail about associations than global developmental assessments can provide. Identifying any early negative effects of maternal psychological distress may offer opportunities for clinical and other interventions to support affected families.

We hypothesized that increasing levels of maternal trait anxiety, perceived stress and depressive symptoms are inversely associated with infant performance on an assessment of congitive development. We examined these influences among women during the pre- and early post-natal period in relation to infant visual reception, language, and motor skills, and overall cognitive development as measured via the Mullen Scales of Early Learning.

METHODS

Study population

Data were collected as part of the prospective Pregnancy, Infection, and Nutrition Study (PIN) and its follow-up cohorts, PIN Postpartum and PIN Babies (17–19). The university biomedical Institutional Review Board approved all protocols; all participants provided written informed consent.

Women (n=1,169) were eligible for PIN Postpartum if they completed the PIN Study (phase 3), agreed to be contacted after delivery, and did not become pregnant again in the first year postpartum. Medical constraints (n=24), inability to recontact (n=207) or schedule (n=62), and refusal (n=187) resulted in 689 women who participated in a visit in the fourth postpartum month. Of these, 45 became pregnant again, 62 were unreachable, 29 moved away, and 20 left the study before the PIN Babies visit at 12 months could be scheduled. The PIN Babies protocol began after PIN Postpartum began, and 125 infants were ineligible because they reached 12 months before the study began conducting the assessments in the home. At the home visit, some did not participate in the Mullen because the child was absent (n=11); or asleep, sick, or fussy (n=21); the mother refused the child's participation (n=8); time ran out (n=3); or other reasons (n=7). A total of 358 mother-infant dyads were included in this analysis.

Data collection

A questionnaire administered before 20 weeks gestation included the State-Trait Anxiety Inventory (STAI)(20–22). The trait score of the STAI is a measure of general feelings of anxiety and is relatively stable over time (20). The home visit interview in the fourth postpartum month included the 10-item Perceived Stress Scale (PSS) to measure the extent to which one's circumstances are perceived as stressful (23). Trait anxiety and PSS scores were analyzed as continuous variables.

Information about depressive symptoms was collected via self-administered questionnaires before 20 weeks gestation and at 24–29 weeks gestation using the Centers for Epidemiologic Studies Depression (CES-D) scale (24). The CES-D measures depressive symptoms in general population samples. The home visit interview in the fourth postpartum month included the Edinburgh Postnatal Depression Scale (EPDS) (25). Each of the depressive symptoms scores was analyzed first as a continuous variable, then two binary variables were constructed to compare those who scored above designated cutpoints multiple times: Women were classified as to whether they had a high number of depressive symptoms throughout pregnancy (CES-D >16 at <20 weeks and 24–29 weeks of pregnancy) and also whether they had a high number of symptoms postpartum as well (as previous with EPDS >9). The 16/17 cutpoint for the CES-D was chosen because of the previously reported reduced specificity of the CES-D using the 15/16 cutpoint for pregnant women (26).

Gestational age was based on ultrasound if done before 22 weeks gestation or the date of the last menstrual period, as gleaned from the hospital record. At 12 months postpartum, study staff administered the Mullen following procedures outlined in its manual (24). The Mullen is an increasingly used assessment of cognition and includes 5 sub-scales to separately assess visual reception (visual discrimination and memory), expressive and receptive language, and fine and gross motor development. Mullen raw scores were converted to age-specific t-scores, and the four Mullen cognitive t-scores (Visual Reception, Fine Motor, Receptive Language, Expressive Language) were summed and converted to a standard Early Learning Composite (Composite) score following procedures in the manual (27). Scores were not adjusted for gestational age because we were concerned that the procedure in the manual overcorrected scores for preterm infants. Specifically, we discovered that the age-adjusted mean score for preterm infants was higher than the mean score for term infants for the Composite and all of the Mullen sub-scales except the Fine Motor scale, although the difference was statistically significant for the Receptive Language sub-scale only (age-adjusted mean Receptive Language t-score for preterm infants=49.2, term infants=45.8, t=2.5, p=0.01). However, we included gestational age in our regression models to compensate.

Information on other covariates was collected via questionnaire before 20 weeks gestation (the Rosenberg Self-Esteem Scale, the Medical Outcomes Study (MOS) Social Support scale) or telephone interview at 17–22 weeks gestation (PSS, age, education, income, other demographics) (19,20).

Statistical analysis

After carrying out univariate and bivariate analyses using t-tests, F-tests, and Spearman correlation tests, multiple regression using restricted cubic splines was used to examine the association between maternal anxiety, perceived stress, or depressive symptoms (continuous variables) and infant scores on each of the five Mullen sub-scales and the Composite, adjusted for 6 confounders. Thus, six models were constructed for each exposure. A SAS macro written by Desquilbet and Mariotti for restricted cubic splines was used (28). Restricted cubic splines allow one to examine and characterize an association that is suspected to be non-linear by using higher order piecewise polynomials to accommodate potential changes in the direction of the association across the exposure distribution (28,29). The association is restricted to be linear at the extreme tails of the exposure distribution due to sparse data. We designated knots at the 5^{th}, 50^{th}, and 95^{th} percentiles for simplicity. These techniques allow for graphical representation of the results across the exposure and outcome distributions. If the results for a given model indicated that a linear model provided an adequate fit or that or no association was found (Wald χ^2 p-value > 0.05), we reported the results from a linear model. No adjustment for multiple comparisons was made.

Multiple partial F-tests checked for effect modification by potential covariates identified *a priori*: income, pre-pregnancy body mass index (BMI), education, social support, self-esteem, maternal age, infant sex, gestational age, presence of a spouse/partner, and one or more of trait anxiety, depressive symptoms, and perceived stress depending on the exposure of interest. The change-in-estimate approach was used to select a final confounder set for each set of models (a change of greater than 10% in the beta coefficient for the exposure variable when removed from the linear version of the model for two or more of the sub-scales). For simplicity, these tests for effect modification and confounding were based on linear models.

Finally, to examine whether chronic depressive symptoms throughout pregnancy or with the postpartum period might show a stronger influence than symptoms at a single time point, linear regression models were built to examine the association between high numbers of depressive symptoms at both time points during pregnancy (scores >16 on the CES-D at both pregnancy time points versus less often or fewer symptoms) and Mullen sub-scale scores. An additional set of models focused on the women who had many symptoms throughout pregnancy and postpartum (high CES-D scores as above and EPDS >9) and compared to women with less frequent or fewer symptoms.

To explore whether loss to followup would be an important source of bias in our results, we used inverse probability weighting to control for selection into the PIN Babies study and compared these results with our original results.

RESULTS

To be eligible for this analysis, infants must have completed at least one sub-scale of the Mullen (n=358; 343 completed all). Characteristics of the participants, descriptive statistics for the exposure variables, and mean Mullen scores at each level of each covariate are listed in Table 1. Approximately 18% and 23% of women experienced high numbers of depressive symptoms (CES-D score >16) at less than 20 weeks and 24–29 weeks of pregnancy, respectively. Approximately 17% of women experienced elevated symptoms (EPDS score

>9) postpartum. Higher levels of anxiety, stress, and depressive symptoms were associated with younger maternal age, low self-esteem, low income, and fewer years of education, but not with gestational age or infant sex (Table 1). Anxiety was also associated with lower social support and absence of a spouse or partner. Depressive symptoms at any of the time points were associated with lower social support, depressive symptoms during pregnancy were associated with the absence of a spouse or partner, and depressive symptoms at less than 20 weeks gestation was associated with higher maternal BMI. Higher stress levels were associated with lower social support. Anxiety, stress, and depressive symptoms were positively correlated with each other (Spearman $\hat{\rho}$ for anxiety and stress=0.41 (p=0.04), for anxiety and depressive symptoms (at <20 weeks of pregnancy)=0.78 (p<0.01), for stress and depressive symptoms (at < 20 weeks of pregnancy)=0.44 (p<0.01)).

Infants had mean Mullen t-scores and Composite scores similar to expected for a general population sample of infants, with mean sub-scale t-scores around 50 and a mean Composite score of 99. Inter-rater reliability was 0.83 (95% confidence interval (CI): 0.70, 0.93). Older (r=0.11, p=0.04) and more educated (r=0.16, p<0.01) mothers tended to have infants with higher Fine Motor scores. Infants of women with more education also tended to score higher on the Composite (r=0.15, p<0.01). Preterm infants had lower Gross Motor (t=−2.6, p=0.01), Fine Motor (t=−3.0, p<0.01), and Composite scores (t=−2.8, p<0.01) than term infants.

Results from regression models are displayed in Table 2 (for linear associations and null findings) and the Figure (for models where the Wald test indicated a non-linear form fit the data best). Trait anxiety was associated with gross motor development in a non-linear fashion, with children exposed to low levels of anxiety (e.g., trait anxiety score=23 at the 5th percentile) performing approximately four points better on the gross motor sub-scale than children exposed to the median level of anxiety for this cohort (Figure 1a). Children exposed to the highest levels of anxiety (e.g., trait anxiety score=56 at the 95th percentile) performed similar to the children at the lowest levels, approximately four points better than children exposed to the median level of anxiety. Trait anxiety was not associated with performance on other sub-scales, but increasing levels of anxiety were associated with slightly lower overall cognitive ability as reflected in the Composite score (Table 2). All of these models were adjusted for the set of confounders selected via the change-in-estimate approach: maternal education, self-esteem, infant sex, maternal age, family income, gestational age, presence of a spouse/partner, and pre-pregnancy BMI.

Depressive symptoms at individual time points during pregnancy were not associated with cognitive development (Table 2), but depresssive symptoms postpartum exhibited a non-linear association with gross motor development and receptive language ability (Figures 1b, 1c). Models were adjusted for maternal education, self-esteem, infant sex, maternal age, family income, gestational age, trait anxiety, and PSS at 17–22 weeks gestation. Similar to the results for trait anxiety and gross motor development, these associations were slightly U-shaped. When women were classified as to whether they exhibited high levels of depressive symptoms at multiple time points, several positive associations with cognitive development were observed. Both unadjusted and adjusted results are shown in Table 3. High scores on the CES-D (>16) at both time points during pregnancy was associated with better fine motor development (adjusted β=7.5, 95% CI: 2.5, 12.5). When the postpartum period was included, the association was stronger (adjusted β=9.7, 95% CI: 3.9, 15.5) for women scoring high at all three time points. Gross motor and overall cognition exhibited associations of similar magnitude with these chronic depressive symptoms, although estimates were less precise.

Perceived stress scores were positively associated with overall cognitive ability (Composite) and expressive language ability: each one-point increase in stress score corresponded to a 0.3-point increase in Mullen composite score and a 0.2-point increase in expressive language score (Table 2). Perceived stress was also associated with gross motor development and receptive language ability in a non-linear fashion (Figures 1d, 1e). Children exposed at the tails of the stress score distribution performed better on the gross motor test than children near the median and this association was stronger than what was observed for anxiety or postpartum depressive symptoms. Children whose mothers scored relatively high on the PSS fared better on the receptive language test than those at or below the median on the PSS. All stress models were adjusted for self-esteem, infant sex, gestational age, maternal pre-pregnancy BMI, trait anxiety, and social support.

To address the possibility that women in the PIN study who refused or who were unable to continue participating through the 12-month visit might be more likely to have significant levels of anxiety, stress and depressive symptoms and an infant who would have scored poorly on the Mullen, we examined the available antepartum anxiety, stress and depressive symptoms data. Women who were eligible but refused postpartum participation, or who were unreachable or unable to schedule a visit in the fourth postpartum month were more likely to score above 16 on the CES-D at either antepartum time point and to score in the highest tertile for trait anxiety (OR for CES-D 17+=1.5, 95% CI: 1.1, 2.0; OR for highest anxiety tertile=1.4, 95% CI: 1.1, 1.8) compared to women who participated in the first postpartum visit. Those who participated in the 4-monthpostpartum visit but not the 12-month postpartum visit were more likely to score in the highest tertile for perceived stress than those who participated in both visits (OR for the highest tertile=1.7, 95% CI: 1.1, 2.5), but scored no differently on the EPDS or trait anxiety scales (OR for EPDS 10+=1.2, 95% CI: 0.7, 1.9; OR for highest anxiety tertile=1.0, 95% CI: 0.6, 1.5). It is not possible to determine with available data whether the children who discontinued participation would have had lower Mullen scores. However, we examined other infant characteristics that might be related to Mullen scores. Infants who were born preterm were as likely as term infants to participate in the home visits (χ_1^2 for the first visit=0.18, p=0.67; χ_1^2 for the second visit=0.20, p=0.66). Maternal anxiety, stress, or depressive symptoms were no more strongly associated with an infant being preterm among those who stopped participation after the first postpartum visit compared to those who completed the second visit. Models that included inverse probability weighs to control for selection into the PIN Babies study were similar to but much less precise than the unweighted results (data not shown).

DISCUSSION

In this study we observed no significant negative consequences to cognitive development in infancy from maternal trait anxiety, antepartum and postpartum depressive symptoms, and stress. Only trait anxiety was associated with slightly poorer overall cognitive development at 12 months of age, an approximate one-point decrease in Mullen Composite score for every five-point increase in anxiety. Based on recent studies that suggested potential non-linear associations between maternal psychosocial distress and child development, we examined each association of interest for potential non-linearity and modeled them using restricted cubic splines to provide a clearer sense of the association beyond what can be achieved using some other statistical techniques (12,13). As a result, we observed that postpartum depressive symptoms and perceived stress were associated with receptive language ability in that children exposed to the lowest and highest levels were slightly more advanced than children towards the median of the exposure distributions. The shape of the association was similar for gross motor development, with trait anxiety also being associated with that outcome in a similar manner. We also observed some linear and positive

associations between perceived stress and expressive language and overall cognition and between chronic depressive symptoms and fine motor skills. However, null findings were common, most noticeably for visual reception. Most of the non-linear associations reflect a fairly modest influence of psychosocial distress. In addition, our estimates were less precise at the tails of the exposure distributions, making it difficult to be certain about the shape of the association at particularly the highest levels where data were sparse. Two previous studies that suggested non-linear relationships found that individuals exposed to moderate levels of stress fared similarly or better than those exposed to low levels but found or suggested that high levels of stress were harmful (12,13). If we were able to more precisely model the associations at high exposure levels, we may have seen the regression line turn downward again to reflect a negative association at those levels. However, this cohort of women experienced fairly low levels of stress, anxiety, and depressive symptoms.

This is the first study to highlight u-shaped associations with a downward slope at the low end of the exposure distribution that may not have been apparent in some previous studies with higher mean distress levels, smaller sample sizes, or statistical techniques that could not characterize the associations in a detailed manner at the lowest exposure levels. It is possible that the shape of these associations below the median is flat—our confidence intervals do not rule out this possibility even though the associations were statistically significantly non-linear. In reality, the difference in anxiety, stress level, or depressive symptoms between those at the bottom of the distribution and those at the median is small and may reflect slight differences in question interpretation or perception of personal circumstances more than clinically meaningful differences in psychosocial distress.

We found several positive and linear associations as well. In light of many previous studies that assessed maternal psychosocial distress in relation to infant global development, these findings appear atypical but parallel the findings of DiPietro et al. who found evidence of enhanced development among children exposed *in utero* to moderate (although perhaps not high) levels of maternal psychological distress (13,30,31). When examining depressive symptoms at only 1 time point, the results were consistently null for depressive symptoms during pregnancy. When data from all 3 time points were considered together, it was clear that depressive symptoms present at both pregnancy time points with or without significant postpartum symptoms were associated with improved fine motor ability. Because we relied on symptoms screeners rather than a diagnostic interview, it is possible that only by combining the data in this way were we able to identify women who were experiencing significant depression. Our result for fine motor development parallels that of DiPietro et al. who found a positive association with Bayley Psychomotor Development Index using a similar composite of antepartum and postpartum depression measures. It may be that women who experience elevated stress or depressive symptoms, but who also have access to a number of positive buffers (e.g., good coping skills, spouse present, education, income), provide a slightly more stimulating environment for their infants than women who report low levels, or it could be that providing a stimulating environment for the child increases stress or depressed feelings. Again, this cohort consisted mostly of highly educated women with a partner in their lives.

We explored whether loss to follow-up might partly explain our positive and null findings. We found that women who experienced significant depressive symptoms or anxiety during pregnancy or high stress levels postpartum were somewhat less likely to participate in the study's postpartum phase. If these children would also have scored lower on the Mullen scales than participating children, negative associations would have been biased toward the null. Our analysis that used inverse probability weights to control for selection into the PIN Babies study produced similar, but less precise, results as the unweighted results, so we presented the unweighted results. Women whose children participated at 12 months of age

would have been enrolled in this intensive longitudinal study for a year and a half or longer, suggesting that these women possessed an ability to cope with many personal demands to the extent that they could afford the time and effort of participation, perhaps despite depressed feelings and moderate stress. It is possible that the stressors experienced by the women who continued participation were more positive, reflecting the everyday strains of caring for a new baby, compared with the stressors of the women who discontinued participation, even if their perceptions of stress were nearly as great. While we did not have information to test this hypothesis, it might partially explain our positive associations.

One limitation of this study is lack of generalizability. This is not a general population sample intended to be representative of any particular source population. As such, these results may not apply to other populations. We were also limited by sample size. Stress, anxiety, and depression can occur together and be easily confounded by each other and other demographic factors. While the PSS, STAI, CES-D, and EPDS measure related constructs, they have distinct psychometric properties. The sample size limited our ability to focus on infants exposed to high levels of multiple exposures. However, this study was able to examine the role of several factors that may affect the observed associations between maternal anxiety, stress, and depressive symptoms and infant development. In previous studies, the lack of control for key demographic and psychosocial confounders like self-esteem, maternal age, maternal BMI and others could have contributed to spurious or exaggerated associations between depressive symptoms and infant development.

Most previous studies reporting detrimental effects of maternal anxiety, stress or depression were focused on older children. It is possible that additional or different effects of these exposures might be apparent when the children are older. Ongoing follow-up of similar cohorts will be important for examining any lasting influence of maternal distress during pregnancy and the postpartum period. Nevertheless, the results of the present study support an emerging picture of moderate maternal psychosocial distress as a benign influence on early child development, although this has rarely been reported for children this young.

Several strengths distinguish this study. Few studies have simultaneously assessed multiple aspects of infant development, not just global development, in relation to these exposures. The Mullen offers sub-scales corresponding to specific aspects of cognitive development, while exhibiting high test-retest reliability and correlating strongly with the Bayley Mental Development Index (27). The Mullen has not previously been used to examine the associations between maternal anxiety, stress and depressive symptoms and child development in a sample of typically developing infants. Some previous studies relied on maternal report for measures of infant outcomes which can inflate the association between poor maternal psychological health and infant behavior since depressed mothers may be more critical or less observant of their child's development. This study employed trained interviewers who used standard assessment techniques with high reliability. This study also relied on well-established, validated instruments for measuring anxiety, stress, and depressive symptoms. The CES-D, EPDS, STAI, and PSS are commonly used instruments in psychosocial research and have been applied in many studies of pregnancy or postpartum health (8,14,32,33). These instruments are useful as general screeners and cannot replace a diagnostic interview to identify cases of clinical disorders. As a result, we cannot verify which women may have had clinical depressive or anxiety disorders. However, our use of continuous exposure measures facilitates examination of associations across the entire spectrum, not just for those with a likely clinical diagnosis. The longitudinal design of this study allowed assessment of maternal psychological health in the antepartum and postpartum periods before developmental outcomes were assessed at 12 months. This avoided assessing exposures based on recall or confusing the temporal sequence of the exposures and outcomes. Finally, the size of this study was larger than some previous

studies and allowed for fairly precise effect estimates across the exposure distributions for this cohort.

In this cohort of relatively well-educated and supported women, we observed little detrimental impact from elevated maternal anxiety, depressive symptoms or stress on infant development except for a small negative association with anxiety. Infants exposed to postpartum or chronic elevated maternal depressive symptoms appeared to perform slightly better on tests of fine motor skills, and infants exposed to elevated maternal stress appeared to perform slightly better on our expressive language assessment. A more complex picture emerged for gross motor development and receptive language ability where children at the lowest and highest exposure levels fared better than children near the median, although estimates were less precise at the tails of the distributions. Given the high prevalence of psychological distress among women and the critical early windows of development that coincide with infancy, it is important to continue to study these associations. Continued efforts to follow cohorts as children age to assess future language and general cognitive development would be valuable to see if the associations change with time. Improved understanding of these associations can provide better guidance to clinicians who routinely see families who are dealing with depression, anxiety, or high levels of stress.

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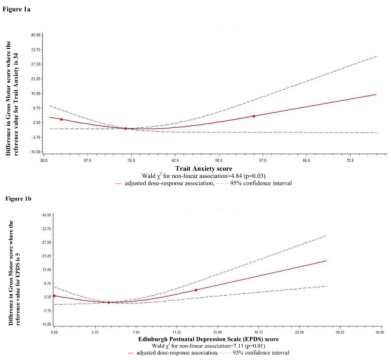

Figure 1c

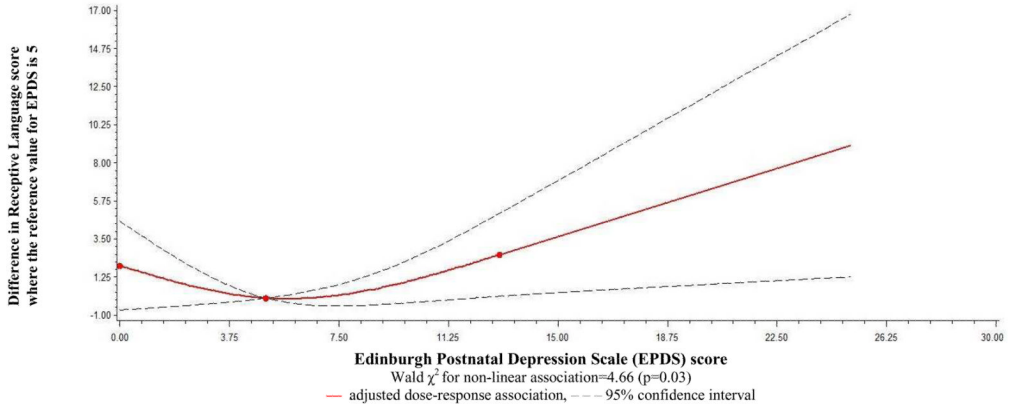

Figure 1d

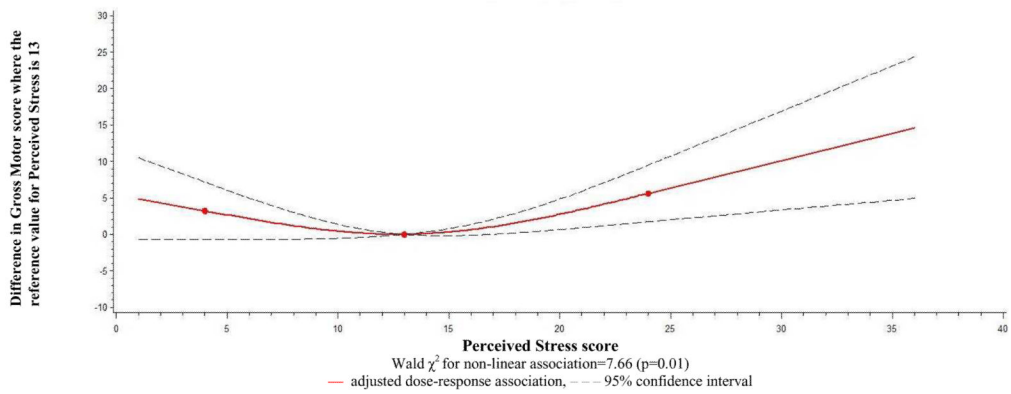

Figure 1e

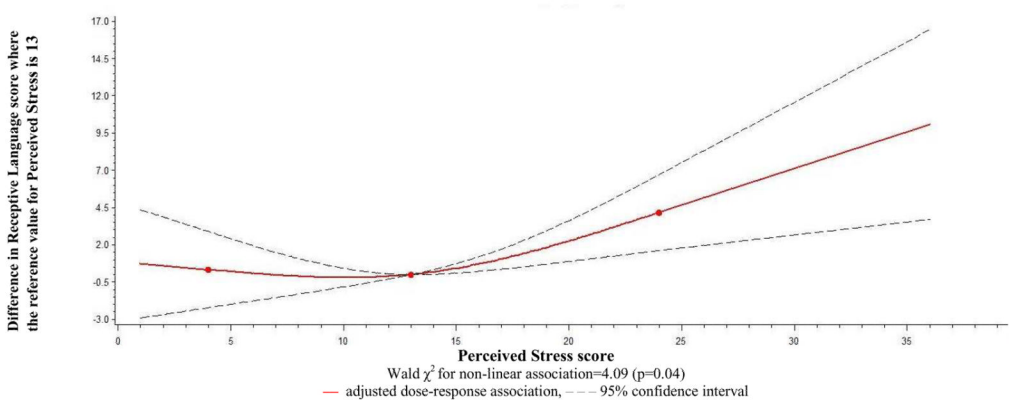

Figure 1.

Restricted cubic splines for non-linear associations between maternal anxiety, depressive symptoms, and stress and scores on the Mullen Scales of Early Learning: Pregnancy, Infection, and Nutrition (PIN), PIN Postpartum and PIN Babies Studies, 2002–2006.

Table 1

Characteristics of mothers and infants in the Pregnancy, Infection, and Nutrition (PIN), PIN Postpartum and PIN Babies Studies and associations with maternal depressive symptoms, trait anxiety, and perceived stress, 2001–2006

Characteristic	State-Trait Anxiety Inventory (trait anxiety score)		Antepartum and postpartum depressive symptoms			Cohen's Perceived Stress Scale score	Mullen Composite
			< 20 weeks of pregnancy (CES-D)	24–29 weeks of pregnancy (CES-D)	Postpartum (EPDS)		
	n (%)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean, SD
All women (n, %)	358 (100)	35.5 (9.8)	10.8 (8.6)	11.3 (8.7)	5.5 (4.1)	13.3 (5.9)	99.4 (13.6)
Spouse/partner present							
Yes	336 (93.9)	34.9 (9.4)[a]	10.0 (7.8)[a]	10.8 (8.2)[a]	5.4 (3.9)	13.1 (5.7)	99.6 (13.5)
No	22 (6.2)	45.7 (9.9)	22.8 (12.0)	19.8 (11.9)	7.9 (5.7)	16.5 (7.9)	99.7 (16.1)
Maternal education							
0–12 years	50 (14.0)	43.8 (12.1)[b]	19.7 (12.7)[b]	18.5 (11.4)[b]	7.8 (4.8)[b]	16.4 (6.7)[b]	95.7 (14.7)
13–16	177 (49.4)	35.6 (9.2)	10.3 (7.5)	11.1 (8.3)	5.2 (3.9)	13.1 (5.7)	99.0 (13.8)
>16	131 (36.6)	32.7 (8.1)	8.5 (6.3)	9.1 (7.0)	5.0 (3.6)	12.4 (5.5)	101.5 (12.7)
Infant sex[c]							
Male	193 (53.9)	35.2 (9.3)	10.5 (7.6)	10.9 (7.7)	5.4 (3.9)	13.3 (5.6)	97.1 (12.8)
Female	164 (45.8)	35.8 (10.4)	11.0 (9.7)	11.8 (9.8)	5.7 (4.3)	13.4 (6.3)	102.3 (14.0)
Pre-preganancy BMI[c,d]							
<19.8	52 (14.5)	33.9 (8.5)	10.5 (7.8)[e]	10.8 (6.6)	5.6 (4.5)	13.0 (5.6)	97.7 (12.4)
19.8–26.0	211 (58.9)	35.0 (9.4)	9.7 (7.4)	10.8 (8.6)	5.4 (3.9)	13.1 (5.9)	100.9 (13.3)
>26.0–29.0	31 (8.7)	35.8 (8.0)	12.0 (9.4)	11.9 (10.2)	6.2 (4.5)	14.5 (6.7)	96.6 (12.1)
>29.0	63 (17.6)	38.5 (12.1)	13.9 (11.4)	13.4 (9.8)	5.5 (4.1)	14.0 (6.0)	97.8 (15.8)
	Mean (SD)		Spearman's $\hat{\rho}$ (p-value)				
Self-esteem[c]	51.3 (8.0)	−0.77 (<0.01)	−0.67 (<0.01)	−0.57 (<0.01)	−0.44 (<0.01)	−0.39 (<0.01)	−0.01 (0.86)
Social support[c]	81.5 (13.9)	−0.52 (<0.01)	−0.50 (<0.01)	−0.40 (>0.01)	−0.29 (<0.01)	−0.27 (<0.01)	0.05 (0.35)
Maternal age	30.2 (5.4)	−0.24 (<0.01)	0.24 (<0.01)	−0.16 (<0.01)	−0.16 (<0.01)	−0.15 (<0.01)	0.04 (0.50)
Family income (% of poverty level)[c]	442.9 (217.1)	−0.27 (<0.01)	−0.31 (<0.01)	−0.31 (<0.01)	−0.22 (<0.01)	−0.26 (<0.01)	0.14 (0.01)
Gestational age[f]	38.6 (2.2)	−0.02 (0.77)	−0.03 (0.64)	−0.09 (0.12)	−0.04 (0.46)	−0.04 (0.49)	0.26 (<0.01)

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[a] t-test $p<0.01$

[b] F-test $p<0.01$

[c] 1 woman was missing data for BMI, 24 for self-esteem, 24 for social support, 11 for income, and 1 child was missing data for sex.

[d] Body Mass Index

[e] F-test $p=0.01$

[f] 12.6% of infants were born preterm (<37 completed weeks)

Table 2

Result of multiple regression models for the associations between maternal anxiety, depressive symptoms, and stress and scores on the Mullen Scales of Early Learning: Pregnancy, Infection, and Nutrition (PIN), PIN Postpartum and PIN Babies Studies, 2001–2006

Mullen Scales of Early Learning	State-Trait Anxiety Inventory (trait anxiety score)[a]	Antepartum and postpartum depressive symptoms[b]			Cohen's Perceived Stress Scale score[c]
		< 20 weeks of pregnancy (CES-D)	24–29 weeks of pregnancy (CES-D)	Postpartum (EPDS)	
		β (95% CI) Adjusted model (for linear associations)			
Gross motor	Non-linear (see Figure 1a)	0.1 (−0.2, 0.3)	0.0 (−0.2, 0.2)	Non-linear (see Figure 1b)	Non-linear (see Figure 1d)
Visual reception	−0.2 (−0.4, 0.1)	0.0 (−0.2, 0.3)	0.0 (−0.2, 0.2)	−0.1 (−0.4, 0.3)	0.0 (−0.2, 0.3)
Fine motor	0.0 (−0.2, 0.2)	0.0 (−0.3, 0.2)	0.0 (−0.2, 0.2)	0.1 (−0.2, 0.5)	0.1 (−0.1, 0.4)
Receptive Language	−0.1 (−0.2, 0.1)	0.1 (−0.1, 0.2)	0.0 (−0.2, 0.1)	Non Linear (see Figure 1c)	Non-linear (see Figure 1e)
Expressive Language	−0.1 (−0.3, 0.1)	0.1 (−0.1, 0.3)	0.0 (−0.1, 0.2)	0.1 (−0.2, 0.4)	0.2 (0.0, 0.4)
Composite	−0.2 (−0.4, 0.0)	0.1 (−0.2, 0.3)	0.0 (−0.2, 0.2)	0.1 (−0.3, 0.5)	0.3 (0.0, 0.6)

[a] Covariates include maternal education, self-esteem, infant sex, maternal age, family income, gestational age, presence of a spouse/partner, and pre-pregnancy body mass index.

[b] Covariates include maternal education, self-esteem, infant sex, maternal age, family income, gestational age, trait anxiety, and perceived stress score (17–22 weeks gestation).

[c] Covariates include self-esteem, infant sex, gestational age, maternal pre-pregnancy body mass index, trait anxiety, and social support.

Table 3

Results of linear regression models for the association between maternal depressive symptoms throughout pregnancy with or without symptoms postpartum and scores on the Mullen Scales of Early Learning: Pregnancy, Infection, and Nutrition (PIN), PIN Postpartum and PIN Babies Studies, 2001–2006

	High depressive symptoms throughout pregnancy[a]		**High depressive symptoms throughout pregnancy and postpartum[b]**	
	Yes=37 (12.0%), No (ref)=272 (88.0%)		**Yes=22 (7.1%), No (ref)=287 (92.9%)**	
Mullen Scales of Early Learning	β (95% CI) Unadjusted model	β (95% CI) Adjusted model[c]	β (95% CI) Unadjusted model	β (95% CI) Adjusted model[c]
Gross motor	2.5 (−1.7, 6.7)	5.1 (−0.6, 10.8)	4.7 (−0.6, 10.0)	6.1 (−0.4, 12.6)
Visual reception	−0.9 (−4.8, 2.9)	4.5 (−0.6, 9.7)	−0.6 (−5.5, 4.3)	2.4 (−3.6, 8.3)
Fine motor	2.3 (−1.5, 6.2)	7.5 (2.5, 12.5)	5.6 (0.6, 10.6)	9.7 (3.9, 15.5)
Receptive Language	0.7 (−2.0, 3.4)	2.0 (−1.6, 5.7)	1.4 (−2.0, 4.9)	2.3 (−1.9, 6.4)
Expressive Language	0.0 (−3.1, 3.1)	−0.9 (−5.1, 3.3)	0.4 (−3.6, 4.4)	−1.3 (−6.1, 3.5)
Composite	1.3 (−3.4, 6.0)	6.8 (0.6, 12.9)	4.0 (−2.1, 10.1)	7.1 (−0.1, 14.3)

[a] Scored >16 on the Center for Epidemiologic Studies-Depression Scale at <20 weeks and 24–29 weeks of pregnancy

[b] Scored >16 on the Center for Epidemiologic Studies-Depression Scale at <20 weeks and 24–29 weeks of pregnancy and > 9 on the Edinburgh Postnatal Depression Scale in the fourth postpartum month

[c] Covarites include maternal education, self-esteem, infant sex, maternal age, family income, gestational age, trait anxiety, and perceived stress score (17–22 weeks gestation).