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Association of maternal psychosocial stress with newborn body composition in the Healthy Start study

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Abstract

Maternal psychosocial stress is associated with delivery of both small- and large-for-gestational-age newborns. Prior studies have relied on methods that do not capture fat mass (FM) vs. fat-free mass (FFM). We aimed to assess the relationship of maternal psychosocial stress, using the Edinburgh Postnatal Depression Scale (EPDS) and Cohen's Perceived Stress Scale (PSS), with newborn body composition. The sample included 604 mother/newborn pairs in the Healthy Start study. We used linear regression to examine associations of EPDS (>6.5 vs. ≤6.5) and PSS (>21 vs. ≤21) with newborn adiposity (FM and %FM measured by air displacement plethysmography [ADP], BMI-for-age, weight-for-length, and weight-for-age z-scores) and lean mass (FFM and length-for-age z-score). Average age of the women was 29.2 ± 6 y. Fifty-five percent of the women were white, 26.2% Hispanic, and 12.1% Black. Twenty-four percent of women had EPDS >6.5 and 18.1% had PSS >21. Mean ± SD birthweight was 3136 ± 437 g. After adjustment for confounders, EPDS >6.5 vs. ≤6.5 corresponded with 35.3 (95% CI: 6.6, 64.0) g lower offspring FM and 0.18 (−0.03, 0.39) units shorter length z-score. PSS was not associated with any neonatal outcomes. Maternal psychosocial stress is associated with delivery of shorter newborns with less FM.

Introduction

Maternal psychosocial stress, resulting from acute stressors during pregnancy such as financial and economic instability and lack of social support[1] and/or lifetime experiences of bias and discrimination,[2] can have adverse effects on fetal growth. The effect of maternal stress on fetal growth and development is thought to operate, in part, through disruption to the hypothalamic–pituitary–adrenal (HPA) axis[1] which, in turn, leads to dysregulation of maternal–fetal pathways involved in energy balance and fat accrual.[3,4]

Prior studies have linked maternal psychosocial stress to delivery of both small-[5–7] and large-for-gestational-age newborns.[3,8] As discussed in a 2018 meta-analysis[6] and a 2015 review[5] and subsequent empirical studies in both developing[9] and developed settings,[7] experiences of maternal stress and anxiety during pregnancy are associated with preterm delivery and smaller newborn size based on birthweight-for-gestational-age.[5,6] At the other end of the spectrum, other studies have found positive associations of maternal stress with newborn size. For example, in a study of 5721 predominantly white mother/offspring pairs in Canada, Melancon et al. observed that women who reported intermediate to high levels of stress during pregnancy, based on the Measure of Psychological Stress (MS-9), had a 1.2- to 1.8-fold greater risk of delivering a macrosomic newborn.[8] Similarly, Entringer et al. found that higher prenatal stress, as determined by cortisol levels, was associated with higher infant adiposity at 6 months of age among 67 diverse mother/child dyads in southern California.[3]

Beyond differences in sociodemographic characteristics of the study samples and method of assessing maternal psychosocial stress, one contributing factor to the inconsistency in study findings is use of relatively crude weight- and length-based indices as proxies for neonatal body composition, which precludes assessment of fat vs. fat-free mass (FFM). Given that there is likely variation in body composition among infants of similar weight and length, direct assessments of body composition in newborns allow for more precise insight into potential consequences of maternal prenatal stress on fetal growth and development.

To address gaps in the literature, we investigated associations of maternal psychosocial stress, based on responses to the Edinburgh Postpartum Depression Scale (EPDS) and Cohen's Perceived Stress Scale (PSS) during pregnancy, with air displacement plethysmography (ADP) assessed fat and FFM, as well as standardized weight- and length-based indices of body size that are commonly used as proxies for adiposity (body mass index [BMI]-for-age, weight-for-length, weight-for-age) and lean mass (length-for-age). Secondarily, we sought to determine whether the relationship between maternal psychosocial stress and neonatal body composition are modified by race/ethnicity. We hypothesized that higher maternal psychosocial stress would be associated with higher neonatal adiposity but not lean mass, and that this relationship differs by race/ethnicity. Specifically, we hypothesized that mothers identifying as non-Hispanic Black would experience higher maternal psychosocial stress, as measured by the EPDS and PSS questionnaires, and therefore deliver smaller-framed newborns with higher neonatal adiposity.

Methods

Study population

Mother/newborn pairs were participants of the ongoing Healthy Start pre-birth cohort, recruited from prenatal obstetric clinics at the University of Colorado Hospital between 2010 and 2014 during the first trimester of pregnancy. Data were collected at three in-person research visits: early pregnancy (median of gestational 17 weeks), mid-pregnancy (median of gestational 27 weeks), and delivery.[10] The initial study population was 1,410 mother/newborn pairs. All mothers provided written informed consent.

For the present analysis, we excluded mothers who were missing responses to either questionnaire ($n = 487$), newborns missing birthweight data ($n = 111$), and those measured more than 2 days after delivery ($n = 208$). After exclusion, the analytic sample included 604 mother/newborn pairs (Supplementary Figure S1). In comparison to the overall sample, mothers in the present analysis had slightly more education (68.3% vs. 67.2% attended college); and the newborns had slightly higher birthweight (3136 vs. 3112 g), higher length z-score (−0.23 vs. −0.37 z-score), as well as lower fat mass (FM) (285 vs. 295 g) and higher FFM (2858 vs. 2833 g).

Exposure: maternal psychosocial stress during pregnancy

The exposures of interest were derived from responses to the Edinburgh Postnatal Depression Scale (EPDS)[11] and Cohen's PSS[12] questionnaires administered at median 17 and 27 gestational weeks. The EPDS is a validated 10-item questionnaire used to assess risk of postpartum depression (PPD) by querying the respondent's feelings and level of satisfaction or dissatisfaction with regular activities and behaviors in the prior 7 days via a ranking scale from 0 to 3 (0 = As much as I always could, 1 = Not quite as much now, 2 = Definitely not as much now, 3 = Not at all). Although the EPDS is validated for assessing PPD, lower scores that do not reach the PPD diagnosis threshold (<13) can be interpreted as indications of maternal distress in clinical settings.[13] The PSS is a 10-item questionnaire used to assess the degree to which life situations are deemed unpredictable, uncontrollable, and overwhelming, with each answer scored on a scale of 0–4. The PSS has been shown to have high internal reliability in pregnant populations and has been validated for depressive and physical symptomatology of stress in non-pregnant populations.[14,15] In the analysis, we considered EPDS and PSS as predictors of neonatal adiposity in separate models as these two constructs capture distinct but overlapping psychosocial pathways for which mutual adjustment may represent an overadjustment.

For the analysis, we took the average of the scores for the EPDS and PSS administered at 17 and 27 gestational weeks to capture psychosocial stress across the prenatal period. The recommended threshold for prenatal depression is EPDS score >12 or 13.[11] However, there were too few women with EPDS >12 ($N = 20$, 3.3%). Therefore, we employed a threshold of EPDS >6.5, corresponding with the fourth quartile of EPDS score in our sample. For PSS, we applied the commonly used threshold of >21 as an indicator of elevated stress.[12,16]

Outcome: neonatal body composition and anthropometry

The outcomes of interest were indicators of newborn size and body composition. For adiposity, we focused on ADP-assessed FM and percent fat mass (%FM), while also considering BMI-for-age z-score, weight-for-age z-score, weight-for-length z-score, standardized according to the World Health Organization Growth Standard for infants 0–2 years of age.[17] For newborn lean mass, we focused on ADP-assessed fat-free mass (FFM) and length-for-age z-score.

Covariates

We considered covariates that could confound the relationship between maternal psychosocial stress during pregnancy and newborn size. We selected covariates based on prior knowledge of shared common causes (confounders) of maternal stress and neonatal body composition, as shown in the directed acyclic graph (DAG) depicted in Supplementary Figure S2. These included maternal age (16–24 years old, 25–29 years old, 30–34 years old, 35+ years old) which is a known correlate of prenatal stress and depression[18] as well as a newborn size[19]; maternal education level (less than high school, high school/GED, associate's degree/some college, 4-year college degree, graduate degree) and household income (<$40,000, $40,000–$70,000, >$70,000), and marital status (yes/no) as social factors that influence both perinatal women's health status and neonatal outcomes.[20] Additionally, we conceptualized self-identified race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, other) as an effect modifier given documented differences in wide-ranging health outcomes across racial and ethnic strata.[21] Additional confounders that we considered included parity, maternal diet quality, physical activity level, and pre-pregnancy BMI. Parity was defined as the woman's number of previous live births (0, 1, 2, 3+). Maternal diet quality was measured by the healthy eating index (HEI) and classified into healthy diet (>57) and unhealthy diet (≤57) based on prior findings in this cohort[22,23] and physical activity levels were measured by estimated total energy expenditure according to the Pregnancy Physical Activity Questionnaire.[24] Pre-pregnancy BMI was calculated as pre-pregnancy weight divided by height.[2] In addition, we considered offspring sex as a precision covariate for neonatal body composition in light of sex differences in birth size.[25]

Statistical analysis

Prior to formal analyses, we assessed univariate distributions of all variables to identify deviations from normality and missing values. Next, we conducted bivariate analyses to assess the correlation (Pearson's R^2 and Spearman's Rho) between EPDS and PSS, and of EPDS and PSS scores with background characteristics of the study participants to identify confounders for multivariable analyses. Here, we calculated the % (N) of participants who had scores above the threshold values for EPDS (>6.5) and PSS (>21) for each level

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Table 1. Background characteristics of 604 mother/newborn pairs in the Healthy Start study

Maternal sociodemographic characteristics	N[a]	%
Maternal age		
16–24 years	128	23.5%
25–29 years	110	20.2%
30–34 years	206	37.8%
35 years or older	101	18.5%
Maternal race/ethnicity		
Hispanic	158	26.2%
Non-Hispanic White	330	54.6%
Non-Hispanic Black	73	12.1%
Asian	19	3.2%
Other	24	4.0%
Maternal education		
Less than high school	87	14.4%
High school/GED	105	17.4%
Some college/associate degree	135	22.4%
4-year college degree	148	24.5%
Graduate degree	129	21.4%
Marital status		
Married or cohabiting	493	81.6%
Not married, not cohabiting	111	18.4%
Household income		
<$40,000	160	26.5%
$40,000–$70,000	115	19.0%
>$70,000	208	34.4%
Maternal perinatal characteristics	N[a]	%
Parity		
0	270	44.7%
1	200	33.1%
2	84	13.9%
≥3	50	8.3%
Pre-pregnancy BMI		
Underweight/normal	327	54.1%
Overweight	168	27.8%
Obese	109	18.1%
Newborn characteristics	N[a]	%
Sex		
Male	309	51.2%
Female	295	48.8%
Timing of delivery		
Preterm (<37 weeks)	12	2.0%
Not preterm (≥37 weeks)	592	98.0%
Birth Size[b]		
Small-for-gestational-age	109	18.1%
Appropriate-for-gestational-age	475	78.6%
Large-for-gestational-age	20	3.3%

[a]Counts may not add up to 604 due to missing values.
[b]According to a US birthweight reference (Oken et al. BMC Pediatrics 2003; 3:6).
BMI = body mass index.

of the covariate and used the chi-squared test to assess statistical significance.

For the primary analysis, we started by examining unadjusted associations of dichotomous and continuous EPDS and PSS scores with each newborn outcome using linear regression. In multivariable analysis, we adjusted for covariates that were associated with EPDS and PSS score in the bivariate analysis and are also known determinants of fetal growth: maternal age, race/ethnicity, maternal education level, marital status, pre-pregnancy BMI, and newborn sex.

To assess for effect modification by race/ethnicity, we entered a product term between the maternal stress indicators and race/ethnicity categorized as non-Hispanic White, Hispanic, non-Hispanic Black, and Other. Here, we considered evidence for a statistical interaction as P-interaction <0.05.

In sensitivity analyses, we re-ran all models after excluding infants born <37 weeks gestation, since preterm infants may have inherently different body composition than those born at term.[26] In light of prior evidence that diet quality[22] and physical activity levels[24] during pregnancy influences neonatal body composition, we further adjusted for maternal HEI score (>57 vs. ≤57) and average maternal physical activity and compared the direction, magnitude, and precision of effect estimates before vs. after including these variables.

Across all analyses, we considered an alpha level of 0.05 for statistical significance. All analyses were completed using SAS (version 9.04, Cary, NC, USA).

Results

Table 1 shows background characteristics of the 604 mother/newborn pairs included in the study. Approximately a quarter (24.3%) of the women had an EPDS score >6.5, thereby meeting the threshold for potential prenatal depression, and 18.1% had a PSS score >21, meeting the threshold for elevated stress. Over half (54.6%) of women identified as non-Hispanic White and 26.2% identified as Hispanic. The majority of women (81.6%) were married or living with a partner. Almost half of the mothers (44.7%) were nulliparous, and 27.8% of mothers were categorized as overweight and 18.1% as obese.

Table 2 shows the newborn outcomes. The mean (SD) birthweight of the study sample was 3,136.1 g (437.1 g). Mean (SD) FM was 8.77% (3.82%) FM. Eighteen percent of the infants were small-for-gestational-age, 78.6% were appropriate-for-gestational-age, and 3.3% were large-for-gestational-age. Additional details on maternal and newborn characteristics are in Table 1 and Table 2.

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Table 2. Body composition and anthropometry among 604 newborns in the Healthy Start study

Newborn outcomes	Mean (SD)
Birthweight (g)	3136.1 (437.1)
Fat mass (g)	284.8 (147.1)
Fat mass %	8.8 (3.8)
Fat-free mass (g)	2857.5 (345.9)
BMI-for-age z-score	−0.43 (0.93)
Weight-for-age z-score	−0.31 (0.94)
Weight-for-length z-score	−0.32 (0.93)
Length-for-age z-score	−0.23 (1.08)

BMI = body mass index.

Table 3 shows bivariate associations of background characteristics with EPDS >6.5 and PSS >21. Younger maternal age, non-White race, lower educational attainment, being single, lower household income, and preterm delivery were associated with EPDS >6.5. On the other hand, none of the characteristics were associated with PSS score.

The two exposure variables, EPDS score and PSS score, had a moderate positive correlation; Pearson's $R^2 = 0.47$ and Spearman's correlation (Rho) = 0.46.

Table 4 shows unadjusted associations of EPDS and PSS, both as dichotomous indicators as well as continuously, with the neonatal outcomes. In general, EPDS – whether assessed dichotomously or continuously – was inversely associated with the neonatal outcomes. Mothers with EPDS scores >6.5 delivered newborns with 40.1 g (95% CI: 12.7, 67.4) lower FM and 0.97% (95% CI: 0.26, 1.62) lower %FM, compared to those who scored ≤6.5. Similarly, each 1-unit increment in EPDS score corresponded with 5.6 g (95% CI: 2.3, 9.0) lower neonatal FM. We observed similar associations with the weight- and length-based indicators of body size. On the other hand, PSS was not associated with any of the neonatal outcomes.

Table 5 shows results from multivariable analysis. Here, EPDS remained associated with higher neonatal FM and %FM. For example, after adjusting for maternal age, race/ethnicity, education level, marital status, pre-pregnancy BMI, and newborn sex, mothers with EPDS >6.5 vs. ≤6.5 delivered newborns with 35.3 g (95% CI: 6.6, 64.0) lower FM and 1.0% (95% CI: 0.0, 1.7) lower % FM. Although not statistically significant, we noted similar, albeit marginally significant, inverse associations of EPDS with lean mass indicators. Mothers who scored > vs. ≤ 6.5 on the EPDS questionnaire delivered newborns with 29.2 g (95% CI: −37.3, 95.7) lower FFM ($P = 0.15$) and 0.18 (95% CI: −0.03, 0.39) lower length z-score ($P = 0.09$).

Consistent with the unadjusted analysis, PSS was not significantly associated with the neonatal outcomes, though similar inverse associations were observed (Table 6).

We did not observe consistent evidence of a statistical interaction with maternal stress indicators, with all *P*-interaction >0.05, except for weight-for-length z-score. However, beta estimates within strata of race/ethnicity category did not markedly differ across strata. Therefore, we do not present stratified results.

Excluding newborns delivered <37 weeks did not change findings; therefore, we included all infants in the presentation of results to avoid collider stratification bias due to study sample selection based on an intermediate variable.[27] The inclusion of HEI score and maternal physical activity level in multivariable models did not result in marked differences in the direction, magnitude, or precision of estimates. For example, after additional adjustment for these variables, mothers with EPDS scores > vs. ≤6.5 delivered newborns with 37.0 g (95% CI: 8.2, 65.7) lower FM, and 0.18 (95% CI: −0.03, 0.39) lower length-for-age z-score.

Discussion

Summary of main findings

In this analysis of 604 mother/newborn pairs, higher maternal psychosocial stress during pregnancy, based on our internal definition of being in the highest quartile of EPDS score during pregnancy, was associated with the delivery of smaller newborns that have less FM, and marginally lower FFM and length at birth. On the other hand, the women's score for Cohen's PSS was not associated with any neonatal outcomes.

Our findings of an inverse relationship of EPDS, an assessment of prenatal depression, with neonatal adiposity and lean mass were counter to our hypothesis, as well as some of the existing literature of mother/offspring pairs in comparable settings. For example, in an analysis of 227 multi-ethnic mother/offspring pairs in New York, Ecklund-Flores et al. reported that prenatal depression according to the Center for Epidemiologic Studies Depression Scale (CESD) was associated with higher birthweight, an association that the authors hypothesized may result from higher heart rate among depressed women and thus enhanced placental perfusion.[28] However, our findings do fall in line with other published studies, including several papers included in a 2012 review that identified associations of maternal depression during pregnancy on low birthweight in offspring,[29] as well as recent empirical studies. For instance, in an analysis of 1377 Chinese mother/infant dyads, Li et al. found that EPDS score ≥12 corresponded with over twice the odds of low birthweight.[30] Similarly, in a study of 353 mother/offspring pairs in rural Ghana, Ae-Ngibise et al. reported that maternal experiences of negative life events, a determinant of maternal depression,[31] corresponded with delivery of low birthweight and small-for-gestational-age neonates.[9]

In addition to the inverse relationship between EPDS and indicators of adiposity, we noted marginal inverse associations with FFM and length-for-age z-score. These findings suggest that maternal depression not only affects fetal fat accretion, but may also influence lean mass accrual and length gain *in utero,* both of which serve as bellwethers for future FFM and linear growth.[32] Importantly, these associations were independent of key sociodemographic and lifestyle confounders previously identified as determinants of neonatal body composition.[22,24]

There are several mechanisms by which maternal depression may hinder fetal growth. During pregnancy, the placenta acts as a buffer against negative exposures the mother experiences. However, maternal stress specifically can increase cortisol levels and inflammation, impacting the placenta's buffering activity and can alter the physiological programming of the HPA axis, responsible for fetal development and fat accrual.[1] Second, it is also possible that maternal depression may affect fetal growth and development through lifestyle behaviors and shorter gestation length,[33] though we were able to account for these variables in our analysis and did not observe evidence that these factors were driving the observed inverse association.

Although we did not find any significant associations of the women's PSS score with newborn body composition, we noted that the relationships followed the same inverse trend as observed for

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Table 3. Bivariate associations of maternal Edinburgh Postnatal Depression Scale (EPDS) and Perceived Stress Scale (PSS) scores with background characteristics of 604 mother/newborn pairs

	N[a]	EPDS score [c]>6.5 % (N) p-Value	PSS score [c]>21 % (N) p-Value
Overall	604	24.3% (147)	18.1% (109)
Maternal sociodemographic characteristics			
Maternal age		**0.0025**	0.2902
16–24 years	128	33.6% (43)	12.5% (16)
25–29 years	110	25.5% (28)	20.9% (23)
30–34 years	206	17.0% (35)	16.0% (33)
≥35 years	101	17.8% (18)	19.8% (20)
Maternal race/ethnicity		<**0.0001**	0.9392
Non-Hispanic White	330	16.7% (55)	18.9% (62)
Non-Hispanic Black	73	34.3% (25)	17.8% (13)
Non-Hispanic Other	43	27.9% (12)	18.6% (8)
Hispanic	158	34.8% (55)	16.5% (26)
Maternal education		<**0.0001**	0.3157
Less than high school	87	47.1% (41)	11.5% (10)
High school/GED	105	31.4% (33)	21.9% (23)
Some college/associates degree	135	23.0% (31)	20.0% (27)
4-year college degree	148	18.9% (28)	29.6% (29)
Graduate degree	129	10.9% (14)	15.5% (20)
Marital status		<**0.0001**	0.5789
Married or cohabiting	493	20.7% (102)	18.5% (91)
Not married, not cohabiting	111	40.5% (45)	16.2% (18)
Annual household income		<**0.0001**	0.6807
<$40,000	160	31.3% (50)	18.1% (29)
$40,000–70,000	115	20.0% (23)	21.7% (25)
>$70,000	208	12.5% (26)	16.4% (34)
Maternal perinatal characteristics			
Parity		0.4280	0.7127
0	270	27.0% (73)	18.2% (49)
1	200	22.0% (44)	16.0% (32)
2	84	25.0% (21)	20.2% (17)
≥3	50	18.0% (9)	22.0% (11)
Pre-pregnancy BMI[b]		0.3660	0.2355
Underweight/normal	327	22.6% (74)	15.9% (52)
Overweight	168	24.4% (41)	19.1% (32)
Obese	109	29.4% (32)	23.0% (25)
Newborn characteristics			
Sex		0.8799	0.4933
Male	309	24.6% (76)	19.1% (59)
Female	295	24.1% (71)	17.0% (50)

(*Continued*)

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Table 3. (*Continued*)

	N^a	EPDS score [c]>6.5 % (*N*) *p*-Value	PSS score [c]>21 % (*N*) *p*-Value
Timing of delivery		**0.0364**	0.3768
Preterm (<37 weeks)	12	50.0% (6)	8.3% (1)
Not preterm (≤37 weeks)	592	23.8% (141)	18.2% (108)
Birth size[c]		0.1244	0.1543
Small-for-gestational-age	109	30.3% (33)	22.0% (24)
Appropriate-for-gestational-age	475	22.5% (107)	16.6% (79)
Large-for-gestational-age	20	35.0% (7)	30.0% (6)

[a]Counts may not add up to 604 due to missing values.
[b]According to a US birthweight reference (Oken et al. BMC Pediatrics 2003; 3:6).
[c]Maternal EPDS and PSS scores are averaged across the first two pregnancy visits.
BMI = body mass index.

Table 4. Unadjusted associations of maternal Edinburgh Postnatal Depression Scale (EPDS) and Perceived Stress Scale (PSS) scores with newborn body size and anthropometry among 604 mother/offspring pairs in the Healthy Start study

Newborn outcomes	EPDS score[c] >6.5 β (95% CI)	Per 1-unit EPDS score[c] β (95% CI)	PSS score[c] >21 β (95% CI)	Per 1-unit PSS score[c] β (95% CI)
Adiposity indicators				
Fat mass (g)	**−40.1 (−67.4, −12.7)**	**−5.6 (−9.0, −2.3)**	−10.3 (−41.0, 20.5)	−0.5 (−4.2, 3.2)
Fat mass %	**−1.0 (−1.7, −0.3)**	**−0.1 (−0.2, −0.1)**	−0.3 (−1.1, 0.5)	0.0 (−0.1, 0.1)
BMI-for-age z-score	−0.13 (−0.30, 0.04)	**−0.02 (−0.04, 0.00)**	−0.08 (−0.27, 0.12)	−0.01 (−0.03, 0.01)
Weight-for-age z-score	**−0.25 (−0.42, −0.08)**	**−0.04 (−0.06, −0.02)**	−0.10 (−0.30, 0.09)	0.00 (−0.03, 0.02)
Weight-for-length z-score	0.01 (−0.17, 0.18)	−0.01 (−0.03, 0.02)	−0.02 (−0.22, 0.18)	−0.01 (−0.04, 0.01)
Lean mass indicators				
Fat-free mass (g)	**−66.8 (−131.4, −2.2)**	**−10.3 (−18.2, −2.4)**	−32.4 (−104.7, 39.8)	−0.3 (−8.9, 8.3)
Length-for-age z-score	**−0.33 (−0.53, −0.13)**	**−0.04 (−0.07, −0.02)**	−0.12 (−0.34, 0.11)	0.00 (−0.02, 0.03)

[c]Maternal EPDS and PSS scores are averaged across the first two pregnancy visits.
BMI = body mass index.

EPDS. It is possible that questionnaire-based indicators of psychosocial stress may not completely capture the stress mothers experience during pregnancy. Additionally, the null findings with respect to PSS could be due to the relatively low PSS scores in this study sample, which may make it more difficult to detect associations with offspring outcomes.

Finally, we did not find evidence of effect modification by race/ethnicity. This was unexpected given an established literature, primarily focused on Black Americans, indicating that chronic stress related to experiences of racial bias and discrimination is associated with adverse pregnancy and birth outcomes.[2] The lack of racial/ethnic differences in the relationship between maternal psychosocial stress and newborn outcomes could be because most mothers in our study sample identified as Hispanic or non-Hispanic White. There is evidence documenting more favorable health and pregnancy outcomes among Latinas, despite having more risk factors for adverse outcomes, due to strong social support within their communities – a phenomena known as the Latina paradox.[34] Future studies in populations with a higher proportion of other racial/ethnic groups are warranted.

Strengths and limitations

The primary strength of this study is the use of ADP-measured neonatal body composition, which allows for precise assessment of neonatal fat and FFM. Using these measures in conjunction with the standardized weight and length measurements provides a more accurate and holistic assessment of newborn body composition. Additional strengths include the relatively large study sample, rich covariate data to control for confounding, and prospective study design.

Limitations of this study include potential lack of generalizability to mother/newborn pairs in other geographic regions, those who cannot afford private prenatal care, or those with markedly different sociodemographic composition.

Conclusion

Maternal psychosocial stress, as measured by the EPDS, was associated with delivery of smaller newborns with lower FM, FFM, and birth length. These results add to the growing body of

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Table 5. Adjusted associations of maternal Edinburgh Postnatal Depression Scale (EPDS) score with newborn body size and anthropometry among 604 mother/offspring pairs in the Healthy Start study

	EPDS score[c] >6.5	Per 1-unit EPDS score[c]
Newborn outcomes	β (95% CI)	β (95% CI)
Adiposity indicators		
Fat mass (g)	**−35.3 (−64.0, −6.6)**	**−4.6 (−8.2, −1.1)**
Fat mass %	**−1.0 (−1.7, −0.0)**	**−0.1 (−0.2, 0.0)**
BMI-for-age z-score	−0.09 (−0.27, 0.09)	−0.02 (−0.04, 0.01)
Weight-for-age z-score	−0.15 (−0.33, 0.03)	−0.02 (−0.04, 0.00)
Weight-for-length z-score	−0.02 (−0.21, 0.17)	−0.01 (−0.03, 0.01)
Lean mass indicators		
Fat-free mass (g)	−29.2 (−95.7, 37.3)	−4.2 (−12.4, 4.1)
Length-for-age z-score	−0.18 (−0.39, 0.03)	−0.02 (−0.05, 0.01)

[c]Maternal EPDS and PSS scores are averaged across the first two pregnancy visits.
BMI = body mass index.

Table 6. Adjusted associations of maternal Perceived Stress Scale (PSS) score with newborn body size and anthropometry among 604 mother/offspring pairs in the Healthy Start study

	PSS score[c] >21	Per 1-unit PSS score[c]
Newborn outcomes	β (95% CI)	β (95% CI)
Adiposity indicators		
Fat mass (g)	−19.8 (−51.1, 11.4)	−1.5 (−5.4, 2.3)
Fat mass %	−0.5 (−1.3, 0.3)	−0.1 (−0.2, 0.0)
BMI-for-age z-score	−0.05 (−0.25, 0.15)	0.00 (−0.03, 0.02)
Weight-for-age z-score	−0.08 (−0.28, 0.12)	0.00 (−0.02, 0.02)
Weight-for-length z-score	−0.01 (−0.21, 0.20)	0.00 (−0.03, 0.02)
Lean mass indicators		
Fat-free mass (g)	−22.7 (−94.8, 49.3)	1.0 (−7.9, 9.8)
Length-for-age z-score	−0.09 (−0.32, 0.14)	0.00 (−0.03, 0.03)

[c]Maternal EPDS and PSS scores are averaged across the first two pregnancy visits.
BMI = body mass index.

knowledge regarding the effect of maternal stress and newborn body composition and emphasize a need to identify resources to help women cope with stress during pregnancy which, in turn, can improve not only the woman's well-being but also that of her infant.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S2040174423000223

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Competing interests. None.

Ethical standard. All procedures of the study protocol were performed according to the Declaration of Helsinki[35] of 1975, revised in 2008, and was approved by the Colorado Multiple Institutional Review Board (IRB #09-0563).

Clinical trial registry. The Healthy Start study is registered as an observational study at clinicaltrials.gov (NCT #002273297).

Article summary. Mothers with higher levels of psychosocial stress delivered shorter newborns with less fat mass.

What is known on this subject. Maternal psychosocial stress has been linked to adverse neonatal outcomes regarding birth size and body composition. However, prior research has not considered differences in fat mass vs fat-free mass, an important distinction to make when assessing risk factors for future health outcomes, such as obesity.

What this study adds. This study assesses body composition using a variety of standardized weight- and length-based indices in addition to measures of fat mass and fat-free mass using air displacement plethysmography.

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