Sociodemographic and Biological Factors of Health Disparities of Mothers and Their Very Low Birth-Weight Infants

June Cho, PhD, RN, FAAN; Lung-Chang Chien, DrPH; Diane Holditch-Davis, PhD, RN, FAAN

ABSTRACT

Background: Black mothers and their very low birth-weight infants in the United States have increased risk of adverse neonatal and maternal health outcomes compared with White mothers and infants. Disparities in adverse birth outcomes associated with sociodemographic factors are difficult to quantify and modify, limiting their usefulness in assessing intervention effects.

Purpose: To test hypotheses that (1) the biological factors of maternal testosterone and cortisol are associated with sociodemographic factors and (2) both factors are associated with neonatal health and maternal mental health and healthy behaviors between birth and 40 weeks' gestational age.

Methods: We used a descriptive, longitudinal design. Eighty-eight mothers and very low birth-weight neonates were recruited from a tertiary medical center in the United States. Data on sociodemographic factors and neonatal health were collected from medical records. Maternal mental health and healthy behaviors were collected with questionnaires. Maternal salivary testosterone and cortisol levels were measured using enzyme immunoassays. Data were analyzed primarily using general linear and mixed models.

Results: High testosterone and/or low cortisol levels were associated with younger age, less education, enrollment in a federal assistance program, being unmarried, being Black, poorer neonatal health, and delayed physical growth. Low cortisol level was related to higher levels of depressive symptoms. Black mothers had fewer healthy behaviors than White mothers.

Implications for Practice and Research: Findings confirm that biological factors are associated with sociodemographic factors, and both are associated with neonatal health and maternal mental health and healthy behaviors. We propose using sociodemographic and biological factors concurrently to identify risk and develop and evaluate ante- and postpartum interventions.

Video abstract available at https://journals.na.lww.com/advancesinneonatalcare/Pages/videogallery.aspx?autoPlay=false&videoId=59

Key Words: biological factors, health disparities, maternal healthy behaviors, maternal mental health, neonatal health, sociodemographic factors, very low birth weight, very preterm birth

Rates of very low birth-weight ([VLBW]) (birth weight <1500 g) and very preterm birth (gestational age [GA] <32 weeks) are about 1.0% and 1.6%, respectively, of live birth in the United States. VLBW and very preterm birth are associated with increased risks for necrotizing enterocolitis, intraventricular hemorrhage, bronchopulmonary disorders, and retinopathy of prematurity. The economic and social burdens of preterm birth in the United States are high, with costs averaging $64,815 per preterm birth. Of the $16 billion spent annually on the medical care of preterm infants, $11 billion is spent on care for very preterm infants.[1] The developmental problems of many very preterm infants create another far-reaching burden for families and society. Mothers with VLBW, very preterm infants, especially those whose income is below the poverty line, are at increased risk of mental health problems such as depressive symptoms and anxiety due to the additional financial and social costs.[2]

Racial disparities exist in the prevalence of VLBW and very preterm birth, with rates in Black mothers being 2.6 and 2.5 times those in White mothers,

Author Affiliations: School of Nursing (Dr Cho) and Public Health (Dr Chien), University of Nevada, Las Vegas, and Duke University School of Nursing, Durham, North Carolina (Dr Holditch-Davis).

Research reported in this publication was supported by the National Institute of Child Health and Human Development (NICHD) of National Institutes of Health under Award no. R01HD076871 to the first author. Authors 2 and 3 have no funding to disclose.

Completing Interests Statement: All authors have no competing interests to declare.

Supplemental digital content is available for this article. Direct URL citation appears in the printed text and is provided in the HTML and PDF versions of this article on the journal's Web site (www.advancesinneonatalcare.org).

Ethical Approval: This study was approved by the institutional review board of University of Alabama at Birmingham and Duke University in advance of implementation. Written information consent was obtained from the patients/guardians.

Correspondence: June Cho, PhD, RN, FAAN, School of Nursing, University of Nevada, Las Vegas, 4505 S. Maryland Pkwy, Las Vegas, NV 89154 (june.cho@unlv.edu).

DOI: 10.1097/ANC.0000000000000997

respectively.[3] Black very preterm neonates are also at higher risk for adverse outcomes than White very preterm neonates.[4] These disparities likely stem from a complex interplay of environmental exposures and social, economic, and behavioral factors. Racism and racial discrimination are associated with adverse perinatal outcomes including preterm birth, low birth weight, and neonatal mortality and morbidity.[5] Structural racism contributes to the increased likelihood of Black women living in poverty compared with White women.[6] Black women who are economically disadvantaged, are younger and unmarried, have less educational attainment (less than a high school diploma), and are enrolled in federal assistance programs such as the Special Nutrition Program for Women, Infants, and Children (WIC) or Supplemental Security Income (SSI) are at particularly high risk of adverse perinatal outcomes.[7] Economically disadvantaged Black women also have more obstetric complications such as diabetes, hypertension, antepartum hemorrhage, and chorioamnionitis that are related to adverse birth outcomes than other childbearing women.[8] Not surprisingly, Black mothers with lower incomes and less educational attainment are also at increased risk for mental health issues due to financial, personal, and societal stressors.[9]

In addition to these sociodemographic factors, healthy lifestyle behaviors ("healthy behaviors") are related to birth outcomes. Investigators have reported that rates of smoking and drinking were higher among mothers of preterm infants than those of full-term infants.[10,11] In another study, mothers of VLBW, very preterm infants who smoked cigarettes had more obstetric complications and resumed smoking and drinking during the postpartum period compared with nonsmoking mothers.[12] Those mothers were also less likely to engage in healthy eating and reported more mental health problems such as depressive symptoms than nonsmoking mothers. Researchers have also found that economically disadvantaged Black mothers are more likely to report unhealthy behaviors during pregnancy, including unhealthy eating patterns, physical inactivity, smoking cigarettes, and drinking alcohol, that can affect perinatal outcomes.[13,14]

Interventions to reduce the risk of adverse neonatal health and maternal mental health outcomes in VLBW, very preterm birth have yet to be effective in reducing disparities in these adverse outcomes. The development of such interventions requires measurable, modifiable markers to serve as indicators of risk and intervention targets and to use in the assessment of intervention effects. Yet, the sociodemographic factors associated with adverse neonatal and maternal mental health outcomes can be difficult to quantify. Also, sociodemographic factors are sometimes subjective due to self-report and are almost always difficult to modify. Identification of measurable, modifiable biological factors related to adverse neonatal health and maternal mental health outcomes in VLBW, very preterm birth would improve the identification of at-risk mothers and infants and the assessment of intervention effects. Interventions targeting maternal healthy behaviors—which are modifiable and associated with both neonatal and maternal health outcomes—are a promising area of research. If the identified biomarkers were also associated with maternal healthy behaviors, they could be used to improve the assessment of the effects of behavioral interventions in this at-risk population.

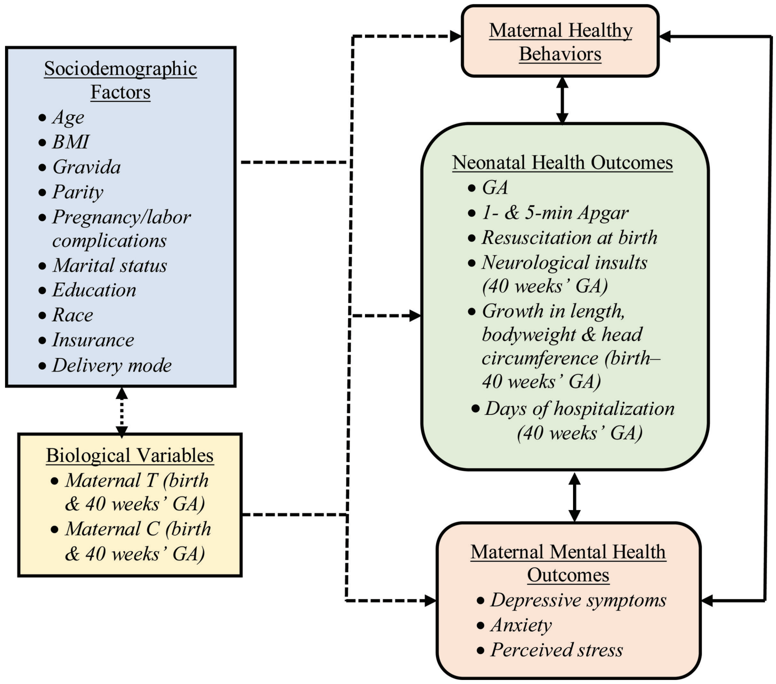
What This Study Adds

- High and/or low F levels are biological risk factors for adverse birth outcomes, neonatal health, and maternal mental health and healthy behaviors between birth and 40 weeks' GA.
- Ways are suggested of assessing health disparities associated with biological and sociodemographic factors and identifying intervention effects.
- Using sociodemographic and biological factors concurrently to identify risk and develop and evaluate ante- and postpartum interventions.

Stress regulation is associated with neonatal health, maternal mental health, and healthy behaviors.[12] As the end products of the hypothalamic-pituitary-gonadal (HPG) and hypothalamic-pituitary-adrenal (HPA) axes, respectively, testosterone (T) and cortisol (F) are both involved in stress regulation. T levels are 18% to 30% higher across the whole pregnancy in Black women than in White women.[15] High maternal T levels (normal range of salivary T in pregnancy is 44.4-86.0 pg/mL) are associated in varying degrees with fetal development, shorter pregnancy longevity, low birth weight and small for GA, and higher levels of maternal depression and parenting stress.[12,16] High levels of psychological stress are sometimes related to increased F levels (normal range of salivary F in pregnancy is 0.21-0.28 μg/dL). However, low F levels have also been found in women experiencing chronic stress. Because of adverse social determinants including low socioeconomic status (SES), housing insecurity, and experience with racism and discrimination, Black women are at higher risk of chronic stress than White women.[17]

In the present study, we hypothesized that, among mothers and their VLBW, very preterm infants, maternal T and F levels would be associated with maternal sociodemographic factors (age, marital status, education, race, body mass index [BMI], obstetric complications during pregnancy and labor, type of health insurance, gravida, parity, and delivery mode) and that both maternal T and F levels and maternal sociodemographic factors would be associated with neonatal health outcomes (GA, Apgar scores, resuscitation at birth, physical

FIGURE 1



Conceptual framework. We hypothesized that, among very low birth-weight, very preterm infants and their mothers, the biomarkers of maternal salivary testosterone (T) and cortisol (F) would be related to sociodemographic factors and that both maternal T and F and sociodemographic factors would be related to maternal healthy behaviors and neonatal health and maternal mental health outcomes. Hypothesized relationships are indicated with dotted lines. BMI indicates body mass index; GA, gestational age.

growth, neurological insults, and days of hospitalization), maternal mental health (depressive symptoms, anxiety, and perceived stress), and maternal healthy behaviors (healthy eating, physical activity, and no use of cigarettes and alcohol; see Figure 1). To test our hypotheses, we collected maternal sociodemographic characteristics at birth, measured maternal salivary T and F levels and neonatal health and maternal mental health variables at birth and 40 weeks' GA, and measured maternal healthy behaviors at 40 weeks' GA in a sample of VLBW, very preterm neonates and their mothers. Our long-term objective was to optimize ante- and postpartum care in this high-risk population, improving outcomes and reducing disparities in neonatal health and maternal mental health outcomes.

METHODS

We used a descriptive, longitudinal research design to examine the associations between biological and sociodemographic factors and between those factors and neonatal health and maternal mental health outcomes and maternal healthy behaviors at birth and 40 weeks' GA.

Participants

We recruited a convenience sample of 88 mothers of VLBW, very preterm neonates from a neonatal intensive care unit (NICU) of a tertiary medical center in southeastern United States. We approached mothers for participation within 3 days after birth to avoid overwhelming them. Mothers were eligible if they were older than 15 years, spoke English, and were the primary caregiver of the neonate. To reduce potential confounding effects, mothers were excluded if they were dependent on narcotics or other recreational drugs, were HIV positive, or had a documented serious medical or psychological problem such as cancer or postpartum psychosis.

Measures

We collected data via review of medical records, interview, and standardized questionnaires. Salivary T and F levels were measured using enzyme immunoassay (EIA).

Sociodemographic Information and Pregnancy History

Data on age, marital status, education, race, BMI, and type of health insurance were collected from demographic data forms at the NICU or interview by the research nurse. Pregnancy history (gravida and parity, obstetric complications during pregnancy and at labor, and mode of delivery) was collected from the neonate's medical record. Obstetric complications during pregnancy included diabetes, use of insulin, pregnancy-induced hypertension, chronic hypertension, antepartum hemorrhage, and chorioamnionitis. Obstetric complications at labor included prolonged prelabor rupture of membrane, use of antenatal steroids, use of antibiotics, and number of antibiotics used. Total scores for pregnancy and labor complications were calculated on the basis of the presence of 6 complications (yes = 1, no = 0) that ranged from 0 to 6, with higher scores indicative of more health problems.

Data on neonatal health outcomes were also collected from the neonate's medical records. GA, 1- and 5-minute Apgar scores, and resuscitation at birth were collected at birth. Neonatal anthropometric measures (body weight, length, and head circumference) were collected at birth and 40 weeks' GA. Neurological insults, as measured by the Neurobiologic Risk Score (NBRS), technology dependence, and days of hospitalization were collected at 40 weeks' GA. The score for resuscitation at birth, which ranged from 0 to 6, was calculated on the basis of the use of 6 treatments, including oxygen, bagging and mask, continuous positive airway pressure (CPAP), intubation, chest compression, and epinephrine. Higher scores indicate more treatment. The NBRS is the sum of scores for 7 possible neurological insults, including infection, blood pH, seizures, intraventricular hemorrhage, assisted ventilation, periventricular leukomalacia, and hypoglycemia. It ranges from 0 to 28, with higher scores indicating a higher prevalence of insults.[18] The technology dependence score, calculated at 40 weeks' GA or discharge (if earlier than 40 weeks' GA), was based on the use of 6 treatments including oxygen, gastrostomy (G)-tube/tube feeding, ventilator/CPAP, tracheostomy, apnea monitor, and medication. Scores ranged from 0 to 6, with higher scores indicating more treatment.

Maternal Mental Health

We used self-report questionnaires to assess maternal mental health status.

Depressive Symptoms

We used the 20-item Center for Epidemiologic Studies Depression Scale (CES-D)[19] to assess maternal depressive symptoms at birth and 40 weeks' GA. Scores range from 0 to 60, with higher scores indicating a higher level of depressive symptoms. Internal consistency using the Cronbach α was reported as 0.85 to 0.90.[19] In the present study, it ranged from 0.87 at birth to 0.89 at 40 weeks' GA.

Perceived Stress

We used the 10-item version of Cohen's Perceived Stress Scale (PSS-10)[20] to assess maternal perceived stress at birth and 40 weeks' GA. Scores range from 0 to 40, with higher scores indicating a higher level of perceived stress. Internal consistency using the Cronbach α was reported as 0.73 to 0.84.[20] In the present study, it ranged from 0.84 at birth to 0.87 at 40 weeks' GA.

Anxiety

We used the 6-item short form of the Spielberg State–Trait Anxiety Inventory (STAI/SF)[21] to assess maternal anxiety at birth and 40 weeks' GA. Scores range from 6 to 24, with higher scores indicating a higher level of anxiety. Internal consistency using the Cronbach α was reported to be 0.83 and was correlated with the 20-item full form of the STAI (r = 0.95).[21] Internal consistency in the present study ranged from 0.82 at birth to 0.89 at 40 weeks' GA.

Healthy Lifestyle Behaviors

As mothers of VLBW infants are short on time and energy due to the demanding physical and emotional needs of their infants, we modified the Life Index Questionnaire (LIQ),[22] a measure of healthy lifestyle behaviors, so that it would require only 5 minutes to complete. The modified LIQ consists of 5 factors: healthy eating, physical activity, previous use of cigarettes, current use of cigarettes, and current use of alcohol. We asked mothers to complete the LIQ only at 40 weeks' GA because mothers had to be home to report their daily healthy behaviors. Total score ranges from 15 to 107, with a higher score indicating more healthy behaviors (ie, more balanced diet, more regular strenuous physical activity, fewer cigarettes, and less alcohol per week). The stability of the LIQ for the 5 factors, using the intraclass correlation coefficient, ranged from 0.74 to 0.92 at 40 weeks' GA.

Biochemical Measurement

Women at high risk for very preterm birth are often treated with glucocorticoids to prevent fetal respiratory dysfunction. The effects of treatment with prenatal glucocorticoids last 7 days,[23] which could affect F levels in these mothers the first week after birth. We measured salivary T and F levels both within 72 hours of birth and at 40 weeks' GA, by which time any effects of prenatal glucocorticoids would have disappeared. Free steroids (protein-unbound) in saliva are more physiologically meaningful, noninvasive, and simpler to assay than total steroids (protein-bound) in the blood.[24] Samples were collected between 9:00 AM and 12:00 PM to minimize effects of diurnal variation. We asked mothers to refrain from drinking or eating in the hour before saliva collection. Because cotton and commercial collection devices interfere with T assays,[24] we asked mothers to spit saliva (1.0 mL) through a straw into a 2-mL Eppendorf microcentrifuge tube. Since T release is episodic, we collected 3 saliva samples at 15-minute intervals at both birth and 40 weeks' GA and combined them before analysis. All samples were stored at −80°C freezer until analysis. Salivary T and F levels were determined using EIA. Levels of T and F were each measured twice to ensure accuracy.

Procedure

The university's institutional review board approved this study. A research nurse identified eligible mothers for the study using the NICU admission log, described the study to the mothers, and gave them informed consent forms to review. After obtaining written informed consent, the research nurse reviewed the medical records and interviewed mothers to collect sociodemographic and neonatal health data. The research nurse asked mothers to complete the CES-D, STAI/SF, and PSS-10 at birth (ie, within 72 hours after birth) and 40 weeks' GA and the LIQ at 40 weeks' GA. After confirming that mothers had not drunk or eaten in the previous hour, the research nurse also collected saliva samples at both time points. If the infant was discharged from the hospital earlier than 40 weeks' GA, the research nurse completed the questionnaires and saliva collections with the mother on the day of discharge.

Data Analysis

We used general linear models (GLMs), general linear mixed models (GLMMs), and generalized linear models (GLIMs) to examine associations between (1) maternal T and F levels and sociodemographic factors (age, marital status, education, race, BMI, type of health insurance, gravida and parity, obstetric complications during pregnancy and at labor, and delivery mode); (2) maternal sociodemographic factors and neonatal health (GA, Apgar scores, resuscitation at birth, and growth in body weight, length, and head circumference), maternal mental health (depressive symptoms, anxiety, and perceived stress), and maternal healthy behaviors (healthy eating, physical activity, and use of cigarettes and alcohol); and (3) maternal T and F levels and neonatal health, maternal mental health, and maternal healthy behaviors at birth and 40 weeks' GA. In the case of twins (n = 4 sets), we randomly chose one of the 2 neonates for analysis.

We analyzed associations between maternal T and F levels and sociodemographic factors using GLM for continuous variables (eg, age and BMI), GLIM Poisson for count variables (eg, obstetric complications), and logistic regression for dichotomous variables (marital status [married vs unmarried], education [high school or less vs more than high school diploma], race [Black vs White], and mode of delivery [vaginal vs cesarean delivery]). For associations between maternal sociodemographic factors and neonatal health, maternal mental health, and maternal healthy behaviors, we used GLM for continuous variables (eg, GA and Apgar scores) and GLMM for longitudinal data (eg, neonatal physical growth in body weight, length, and head circumference) and maternal mental health (depressive symptoms, anxiety, and perceived stress) between birth and 40 weeks' GA. We analyzed associations between maternal T and F levels and neonatal health, maternal mental health, and maternal healthy behaviors using GLM for continuous variables (eg, neonatal days of hospitalization and maternal healthy behaviors) and GLMM for longitudinal data such as neonatal growth and changes in maternal mental health from birth to 40 weeks' GA.

We used log transformation to meet the assumption of normality for several variables including T and F levels at birth and 40 weeks' GA. Data analyses were conducted using SPSS, version 24 (IBM Corp, Armonk, New York), and the significance level was set at .05.

RESULTS

Maternal Sociodemographic Characteristics and Neonatal Health

Table 1 provides maternal sociodemographic and neonatal demographic and health characteristics. Mean maternal age was 28 years. The majority of mothers were Black (58%), had more than a high school education (54%), were unmarried (55%), completed 2 doses of prenatal glucocorticoid treatment (85%), and had obstetric complications during pregnancy (85%) and/or at birth (100%). The number of obstetric complications did not differ significantly between Black and White mothers. Less than half (41%) were enrolled in federal assistance programs such as WIC or SSI. Mean scores out of 6.0 were 2.1 for resuscitation at birth and 0.5 for technology dependence at 40 weeks' GA. "Mean days of hospitalization" at 40 weeks' GA was 69.6.

Associations Between Maternal Biological and Sociodemographic Factors

Means of maternal T and F levels were 58.61 pg/mL and 0.15 μg/dL at birth and 55.77 pg/mL and 0.23 μg/dL at 40 weeks' GA, respectively. Table 2 shows that younger maternal age and less educational attainment (high school diploma or less) were associated with higher T and lower F levels. Mothers with higher T levels and those with lower F levels were also more likely to be Black and unmarried. Mothers with higher T levels were less likely to have private health insurance. Maternal BMI, gravida and parity, obstetric complications during pregnancy and at birth, and delivery mode (vaginal vs cesarean delivery) were not associated with either T or F levels.

TABLE 1. Maternal Sociodemographic and Neonatal Demographic and Health Characteristics (N = 88 Dyads)[a]

Variable	Min	Max	Mean or %	SD
Maternal				
Age, y	18	43	28.3	6.1
Gravida	1	11	2.8	1.8
Parity	1	6	2.0	1.1
BMI, kg/m^2	20.7	49.4	32.9	6.9
Pregnancy complications[b]	0	3	1.0	0.8
Labor complications[c]	2	5	4.0	1.0
Race, %				
Black			58.0	
White			42.0	
Education: more than HS diploma,[d] %			54.3	
Medical insurance: private, %			59.3	
Marital status: married, %			44.8	
Delivery mode: vaginal, %			34.1	
Complete steroid: yes, %			85.2	
Neonatal				
Gender: male, %			36.4	
GA, wk	24.2	33.5	28.6	2.1
1-min Apgar score	0	9	5.0	2.5
5-min Apgar score	1	9	7.2	1.7
Resuscitation at birth[e]	0	4	2.1	1.0
Body weight, g				
Birth	450	2310	1070.8	330.5
40 wk' GA	1206	3350	2214.6	427.2
Length, cm				
Birth	25.0	44.5	38.1	3.6
40 wk' GA	31.0	50.0	48.5	43.5
Head circumference, cm				
Birth	20.0	33.0	33.0	25.5
40 wk' GA	26.0	45.5	45.5	31.7
Technology dependence[f]	0	4	0.5	0.9
NBRS	0	9	1.9	2.0
Days of hospitalization	6	161	69.6	34.2

Abbreviations: BMI, body mass index; CPAP, continuous positive airway pressure; GA, gestational age; HS, high school; NBRS, Neurobiologic Risk Score.
[a]Mean is provided unless otherwise indicated.
[b]Number of obstetric complications during pregnancy.
[c]Number of obstetric complications at birth.
[d]Percentage of mothers with more than high school diploma.
[e]Resuscitation at birth = the use of 6 treatments, including oxygen, G-tube/tube feeding, ventilator/CPAP, tracheostomy, apnea monitor, and medication.
[f]Technology dependence = the use of 6 treatments, including oxygen, bagging and mask, CPAP, intubation, chest compression, and epinephrine.

Associations Between Maternal Sociodemographic Factors and Neonatal Health, Maternal Mental Health, and Maternal Healthy Behaviors

As shown in Table 3, higher maternal BMI was associated with higher GA; younger age was associated with higher 1-minute Apgar score; being married was associated with higher 1-minute Apgar score and less-frequent resuscitation at birth; having private insurance was associated with higher 1-minute Apgar score; and being Black was associated with greater growth in length from birth to 40 weeks' GA and fewer healthy behaviors at 40 weeks' GA. Education, obstetric complications, gravida, parity, and delivery mode were not associated with any neonatal health, maternal mental health, or maternal healthy

TABLE 2. Associations Between Maternal Testosterone (T) and Cortisol (F) Levels and Sociodemographic Factors (N = 88 Dyads)

Variable	Parameter	β	95% CI	*P*
GLMs for continuous variables				
Age	T	−7.268	−12.691, −1.844	.009
	F	5.754	2.457, 9.052	.001
BMI	T	−4.499	−10.796, 1.797	.159
	F	.681	−3.292, 4.655	.734
Gravida	T	−.111	−0.359, 0.137	.375
	F	.024	−0.127, 0.175	.755
Parity	T	−.074	−0.277, 0.130	.473
	F	.100	−0.024, 0.224	.112
GLIMs for count variables (Poisson)				
Pregnancy complications	T	.468	−0.431, 1.366	.308
	F	−.271	−0.816, 0.274	.329
Labor complications	T	.153	−0.301, 0.607	.510
	F	−.002	−0.274, 0.271	.989
Logistic regression for dichotomous variables				
Marital status (married)	T	−3.212	−5.504, −0.920	.006
	F	1.690	0.409, 2.970	.010
Education (HS diploma or less)	T	3.194	0.844, 5.544	.008
	F	−1.765	−3.111, −0.419	.010
Race (Black)	T	2.097	0.031, 4.164	.047
	F	−1.910	−3.221, −0.599	.004
Insurance (private)	T	−2.673	−4.921, −0.425	.020
	F	.468	−0.709, 1.645	.436
Delivery mode (vaginal)	T	.885	−1.037, 2.807	.367
	F	−.610	−1.779, 0.559	.306

Abbreviations: β, parameter estimate; BMI, body mass index; CI, confidence interval; GLIMs, generalized linear models; GLMs, general linear models; HS, high school.

behavior variables. There were no associations between sociodemographic variables and 5-minute Apgar score at birth, degree of neurological insults, days of hospitalization at 40 weeks' GA, or change in maternal mental health scores from birth to 40 weeks' GA.

Association Between Maternal Biological Factors and Neonatal Health, Maternal Mental Health, and Maternal Healthy Behaviors

All estimated coefficients of T and F levels at birth and 40 weeks' GA were adjusted by maternal sociodemographic factors (age, race, marital status, education, gravida, parity, BMI, number of obstetric complications during pregnancy and at labor, type of health insurance, and mode of delivery). As shown in Table 4, neonates of mothers with higher T levels and those of mothers with lower F levels spent more days in the hospital and showed slower physical growth in body weight and length. Neonates of mothers with lower F levels also received more resuscitation at birth and showed slower growth in head circumference.

Maternal T levels were not associated with change in maternal mental health from birth to 40 weeks' GA. Maternal F levels were inversely associated with change in the levels of depressive symptoms but were not associated with changes in the levels of either anxiety or perceived stress between birth and 40 weeks' GA. Maternal healthy behaviors were not associated with either T or F levels.

DISCUSSION

In the present study, we hypothesized that, in VLBW, very preterm neonates and their mothers, (1) the biological factors of maternal T and F levels at birth and 40 weeks' GA would be associated with maternal sociodemographic factors and (2) that both factors would be associated with neonatal health outcomes, maternal mental health, and maternal healthy behaviors at birth and 40 weeks' GA. Findings supported

TABLE 3. Associations Between Maternal Sociodemographic Factors and Neonatal Health, Maternal Mental Health, and Maternal Healthy Behaviors (N = 88 Dyads)[a]

Variable	Parameter	β	95% CI	*P*
GLMs for neonatal health outcomes at birth				
GA	Age	−.076	−0.182, 0.031	.160
	Marital status (married)	.988	−0.262, 2.237	.119
	Education (HS or less)	.472	−0.575, 1.519	.372
	Race (Black)	−.335	−1.412, 0.742	.537
	BMI	.076	0.002, 0.151	.046
	Pregnancy complications	−.425	−1.136, 0.286	.237
	Labor complications	−.186	−0.695, 0.323	.469
	Insurance (private)	−.334	−1.440, 0.773	.549
	Gravida	1.393	−1.042, 3.827	.258
	Parity	1.944	−0.990, 4.878	.190
	Delivery mode (vaginal)	−.493	−1.510, 0.524	.337
1-min Apgar score	Age	−.122	−0.243, 0.000	.050
	Marital status (married)	2.731	1.310, 4.153	.000
	Education (HS or less)	.215	−0.973, 1.404	.718
	Race (Black)	.336	−0.890, 1.562	.586
	BMI	.014	−0.072, 0.099	.750
	Pregnancy complications	−.062	−0.874, 0.750	.879
	Labor complications	−.281	−0.867, 0.305	.342
	Insurance (private)	−1.366	−2.635, −0.098	.035
	Gravida	1.234	−1.591, 4.058	.386
	Parity	2.408	−0.941, 5.757	.156
	Delivery mode (vaginal)	1.022	−0.142, 2.186	.084
Resuscitation at birth	Age	−.004	−0.055, 0.047	.874
	Marital status (married)	−.815	−1.417, −0.214	.009
	Education (HS or less)	−.314	−0.818, 0.190	.218
	Race (Black)	−.217	−0.736, 0.301	.406
	BMI	−.006	−0.043, 0.030	.723
	Pregnancy complications	.166	−0.177, 0.508	.338
	Labor complications	.022	−0.223, 0.267	.857
	Insurance (private)	−.038	−0.574, 0.498	.887
	Gravida	.484	−0.688, 1.657	.412
	Parity	−.864	−2.277, 0.548	.226
	Delivery mode (vaginal)	.089	−0.401, 0.579	.719
GLMMs for longitudinal anthropometric measures between birth and 40 wk' GA				
Growth in length from birth to 40 wk' GA	Age	.000	−0.001, 0.001	.778
	Marital status (married)	.009	−0.010, 0.028	.340
	Education (HS or less)	.006	−0.009, 0.022	.421
	Race (Black)	.019	0.002, 0.035	.024
	BMI	.001	−0.000, 0.002	.145
	Pregnancy complications	−.009	−0.020, 0.001	.078
	Labor complications	.002	−0.005, 0.010	.594
	Insurance (private)	.000	−0.016, 0.018	.922
	Gravida	.016	−0.021, 0.054	.395
	Parity	.028	−0.017, 0.074	.216
	Delivery mode (vaginal)	.010	−0.005, 0.025	.208

(*continues*)

TABLE 3. Associations Between Maternal Sociodemographic Factors and Neonatal Health, Maternal Mental Health, and Maternal Healthy Behaviors (N = 88 Dyads)[a] (*Continued*)

Variable	Parameter	β	95% CI	*P*
GLMs for maternal healthy behaviors at 40 wk' GA				
Healthy lifestyle behaviors at 40 wk' GA	Age	−.371	−1.085, 0.343	.302
	Marital status (married)	−3.532	−12.331, 5.267	.425
	Education (HS or less)	6.089	−1.175, 13.352	.099
	Race (Black)	−7.366	−14.621, −0.112	.047
	BMI	−.261	−0.777, 0.255	.316
	Pregnancy complications	.263	−4.606, 5.132	.914
	Labor complications	−.530	−4.124, 3.063	.769
	Insurance (private)	1.930	−5.833, 9.694	.621
	Gravida	−3.936	−21.923, 14.050	.663
	Parity	7.506	−13.748, 28.761	.483
	Delivery mode (vaginal)	−1.884	−8.673, 4.906	.581

Abbreviations: β, parameter estimate; BMI, body mass index; CI, confidence interval; GA, gestational age; GLMs, general linear models; GLMMs, general linear mixed models.

[a]There were no significant associations between demographic factors and 5-min Apgar scores, neurological insults, days of hospitalization, body weight, head circumference, depressive symptoms, anxiety, and perceived stress (data are not shown).

our first hypothesis: we found that high T and low F levels were associated with younger maternal age, less educational attainment, a decreased likelihood of having private health insurance, being Black, and being unmarried. Findings also supported our second hypothesis: T and F levels and sociodemographic factors were associated with neonatal health problems (GA, 1-minute Apgar scores, resuscitation at birth, days of hospitalization, and physical growth), maternal mental health problems (depressive symptoms), and maternal healthy behaviors between birth and 40 weeks' GA. In some of these cases, only biological factors or only sociodemographic factors were associated with a particular outcome.

Research on racial disparities in perinatal health outcomes has primarily focused on sociodemographic and environmental factors. Investigators have reported associations between racial disparities in adverse pregnancy and birth outcomes and educational attainment, marital status, income, access to healthcare, and perceptions of racism, racial discrimination, and structural racism.[17] Perceptions of racial discrimination and structural racism accumulate throughout life, leading to chronic stress that plays a critical role in health outcomes in Black women.[9] These sociodemographic and environmental factors, however, are sometimes difficult to quantify and not easily modified. On their own, then, they do not make ideal markers for precise identification of risk or measurable targets for intervention. Identification of more quantifiable and modifiable factors associated with adverse birth outcomes would be an important step toward optimizing ante- and postpartum care in high-risk mothers and infants and, ultimately, reducing disparities in neonatal health outcomes, maternal mental health issues, and maternal unhealthy behaviors (which are related to mental health).[14] Our findings in the present study suggest that maternal T and F have the potential to serves as biomarkers of adverse outcomes in VLBW, very preterm birth. We propose that using these biomarkers in conjunction with sociodemographic and environmental risk factors would improve our ability to identify at-risk mothers, develop personalized interventions, and evaluate the effects of the interventions.

Associations Between Maternal T and F Levels and Neonatal Health, Maternal Mental Health, and Maternal Healthy Behaviors

We found that high maternal T levels were inversely associated with neonatal health outcomes and physical growth. Neonates of mothers with high T levels spent more days in the hospital and showed delayed physical growth in body weight and length between birth and 40 weeks' GA. Svensson et al[25] reported that a high maternal T level was associated with lower birth weight, small for GA, and shorter gestation, which could contribute to less favorable neonatal health outcomes. The associations between high maternal T levels and low birth weight and small for GA remained even after adjusting for maternal age, BMI, parity, secondhand smoke exposure, education, SES, and infant sex. Other researchers found higher T levels in women who gave birth at preterm versus at full term.[26] The inverse associations between maternal T levels and neonatal health and physical growth outcomes might occur because T levels are positively correlated between mothers and fetuses/infants, especially between mothers and their male fetuses/neonates ($r = 0.43$).[27]

We found that lower maternal F levels were associated with younger age, an increased likelihood of being unmarried, less educational attainment, and

TABLE 4. Associations Between Maternal Testosterone (T) and Cortisol (F) Levels and Neonatal Health, Maternal Mental Health, and Maternal Healthy Behaviors (N = 88 Dyads)[a]

Variable	Parameter	β	95% CI	*P*
GLMs for neonatal health at birth and 40 wk' GA				
GA	T 00	.745	−1.836, 3.325	.566
	F 00	−.565	−2.271, 1.140	.510
1-min Apgar score	T 00	.419	−2.595, 3.434	.781
	F 00	.380	−1.607, 2.367	.703
5-min Apgar score	T 00	.868	−1.339, 3.076	.434
	F 00	.050	−1.409, 1.509	.945
Resuscitation at birth	T 00	.104	−0.108, 0.316	.330
	F 00	−.157	−0.297, −0.017	.029
Neurological insults at 40 wk' GA	T 40W	.166	−0.550, 0.881	.640
	F 40W	.272	−0.310, 0.854	.349
Days of hospitalization at 40 wk' GA	T 40W	66.887	12.013, 121.761	.018
	F 40W	−38.204	−73.837, −2.570	.036
GLMMs for neonatal growth from birth to 40 wk' GA				
Body weight	T	−.182	−0.327, −0.038	.014
	F	.198	0.107, 0.289	.000
Length	T	−.051	−0.096, −0.005	.027
	F	.058	0.029, 0.086	.000
Head circumference	T	−.039	−0.082, 0.003	.072
	F	.052	0.025, 0.078	.000
GLMMs for change in maternal mental health from birth to 40 wk' GA				
Depressive symptoms	T	.335	−0.057, 0.728	.093
	F	−.306	−0.552, −0.059	.016
Anxiety	T	.108	−0.078, 0.294	.251
	F	−.063	−0.186, 0.059	.305
Perceived stress	T	2.725	−3.152, 8.604	.360
	F	−.644	−3.891, 2.602	.694
GLMs for maternal healthy behaviors at 40 wk' GA				
Healthy lifestyle behaviors at 40 wk' GA	T 40W	−.090	−0.229, 0.048	.198
	F 40W	.053	−0.035, 0.141	.230

Abbreviations: β, parameter estimate; CI, confidence interval; F 00, cortisol levels at birth; F 40W, cortisol levels at 40 weeks' GA; GA, gestational age; GLMs, general linear models; GLMMs, general linear mixed models; T 00, testosterone levels at birth; T 40W, testosterone levels at 40 weeks' GA.

[a]All estimated coefficients of testosterone and cortisol were adjusted by maternal demographic factors (age, race, marital status, education, gravida, parity, body mass index, number of obstetric complications during pregnancy and at labor, type of health insurance, and mode of delivery).

being Black. For neonates, low maternal F levels were associated with more resuscitation at birth and were inversely associated with physical growth in weight, length, and head circumference between birth and 40 weeks' GA. In a prior study, Gillespie et al[28] found that higher maternal F levels were predictive of earlier birth among women without, but not those with, racial discrimination. Mothers with chronic stress due to discrimination might have a blunted F response.[29] Our findings in the present study indicate that higher maternal F levels are a protective factor against adverse neonatal health outcomes and delays in physical growth. Other prior studies have also reported positive associations between maternal F levels and perinatal outcomes. Mothers with preterm birth had lower F levels (8.59-9.71 pg/mg) throughout pregnancy than mothers with full-term birth (11.26-23.80 pg/mg).[30] Maternal F levels during the first and third trimesters were positively associated with birth weight, especially for males ($\beta = .17$, $P = .04$).[31] During the postpartum period, higher maternal F levels were positively associated with infant cognitive and gross motor development at 6 months.[32]

The effect of prenatal glucocorticoid treatment, which 85% of mothers in the present study received, was likely a contributor to increased maternal F levels at birth. Nonetheless, maternal F levels were lower at birth (ie, within 72 hours after birth, mean F levels = 0.146 μg/dL) than at 40 weeks' GA (~2-3 months after birth, mean F levels = 0.238 μg/dL). As the effects of glucocorticoids usually last for 7 days,[23] higher F levels at 40 weeks' GA were likely not related to the treatment. It is possible that prenatal glucocorticoid treatment affected the variable of resuscitation for neonates at birth, as its treatment addresses respiratory immaturity, but our findings suggest that it did not have a substantial effect on maternal F levels at birth or 40 weeks' GA.

Cortisol is known to increase susceptibility to mental health problems. For example, high maternal F levels have been associated with negative mood and emotional dysregulation during pregnancy[33] and depressive symptoms at birth and in the postpartum period.[34] Yet, in the present study, high maternal F levels appeared to be protective against maternal depressive symptoms during the postnatal period, as mothers with higher F levels reported lower levels of depressive symptoms between birth and 40 weeks' GA. Likewise, Scheyer and Urizar[35] found that lower maternal F levels from the third trimester to 3 months postpartum were associated with higher levels of perceived stress while lower maternal F levels from the first trimester to 3 months postpartum were associated with higher levels of postpartum depression. The depressed mothers with lower F levels and additional stressors were also younger, more likely to smoke, and had neonates with lower birth weights and more health problems at 4 to 6 weeks after birth. Research has shown that mothers with chronic stress—stemming from sociodemographic factors such as perceived racism and low SES—have a blunted F response and flattened diurnal F curve.[29] As noted earlier, lower F levels in the present study were associated with younger maternal age, an increased likelihood of being unmarried, less educational attainment, and being Black, many of which suggest they were at increased risk of experiencing chronic stress. Another explanation is that the positive association between hypercortisolism and depression and depressive symptoms may be transient, whereas the inverse association between F levels and mental health problems is chronic.[36]

Associations Between Maternal Sociodemographic Factors and Neonatal Health, Maternal Mental Health, and Maternal Healthy Behaviors

In the present study, findings confirmed some associations between sociodemographic factors and adverse neonatal and maternal birth outcomes reported in the literature, but we also had some unexpected findings. Maternal BMI was the only sociodemographic factor associated with very preterm birth, with neonates of mothers with a higher BMI having a higher GA. A higher BMI might be considered a risk factor for adverse pregnancy and birth outcomes because obesity is associated with an increased risk for obstetric complications such as gestational diabetes and hypertension.[37] Manuck[38] reported, in a finding similar to ours, that very preterm birth was decreased in Black women who were obese compared with those with normal weights. In another study, researchers reported that mothers of VLBW, very preterm neonates were more likely to be economically disadvantaged than mothers of full-term infants with normal birth weight and thus could sometimes not afford healthy foods.[39] Economically disadvantaged mothers enrolled in a federal assistance program such as WIC showed a 10% to 20% increase in their intake of optimal foods and nutrients compared with those not enrolled.[39]

Marital status was the sociodemographic factor most frequently associated with birth outcomes in the present study. Neonates of mothers who were married had higher 1-minute Apgar scores and required less resuscitation at birth than those of mothers who were unmarried. Prior studies support our finding of marital status as an important factor for adverse birth outcomes. Shapiro et al[40] reported that mothers who are married may have access to more social and financial resources that can reduce adverse perinatal outcomes including preterm birth, low birth weight, and small for GA. Sullivan et al[41] found that Black mothers born in the United States were less likely to be married (32.4%) than White mothers born in the United States (75.7%). Thus, marital status might be directly related to racial disparities in birth outcomes in the United States as individual factors explain 6% to 7% of health disparities.[17]

Neonates of Black mothers had a faster rate of growth in length than those of White mothers in the present study, though neither growth in weight nor growth in head circumference differed by race. This finding is contrary to that of Tarca et al,[42] who reported that mean birth weight at 40 weeks' GA was 133 g higher for neonates born to White mothers than those born to Black mothers. Barrett et al[15] found that Black women were more likely to have high T levels than White women, while Svensson et al[25] found that high T levels were inversely associated with birth weight and physical growth.

We did not find any associations between maternal sociodemographic factors (age, marital status, educational attainment, race, BMI, and type of health insurance) and changes in maternal mental health between birth and 40 weeks' GA. A possible explanation is that maternal mental health problems might be reduced by time, but we analyzed the data longitudinally. Indeed, anxiety levels were significantly higher at birth in mothers who were unmarried than in those who were married, but the difference was no longer significant at 40 weeks' GA.

Only race was associated with healthy behaviors in the present study. Black mothers reported fewer healthy behaviors at 40 weeks' GA than White mothers, including healthy eating, physical activity, and refraining from smoking cigarettes and drinking alcohol. Olendzki et al[43] reported that, in an urban area in the District of Columbia, 50% of Black and 14% of White women older than 65 years had unhealthy eating patterns. Research has provided evidence that the prevalence of smoking and drinking during pregnancy differs on the basis of sociodemographic factors, with the rate of smoking being higher in urban areas of the United States (10.4%) than in the country as a whole (7.2%).[10] Neighborhoods with a greater percentage of residents living in poverty and being uninsured have more tobacco stores nearby than neighborhoods where residents have higher SES.[13] Cho et al[12] reported that, in mothers of VLBW infants, higher maternal T levels were associated with increased smoking and depressive symptoms while higher maternal F levels were associated with more healthy behaviors. As healthy behaviors have been associated with birth outcomes, neonatal health, and maternal mental health, they are a promising target for behavioral interventions to reduce risks of adverse outcomes.[10-12] Findings from the present study and those of Cho et al[12] suggest that healthy behaviors might be associated with both sociodemographic and hormonal biomarkers. Further study into these associations is warranted as part of the effort to reduce disparities in neonatal and maternal health among high-risk populations.

Study Limitations and Recommendations for Future Studies

This study had a few limitations. We were not able to recruit Hispanic or Asian mothers of VLBW, very preterm neonates because their numbers were so small at the recruitment site. Future studies should use quota sampling to include more racially diverse samples of mothers. They should also have multiple recruitment sites to explore potential regional effects. We used EIA to measure hormone levels in saliva in the present study. Immunoassays, however, overestimate hormone levels.[44] For future studies, liquid chromatography–mass spectrometry (LC/MS) might offer increased sensitivity and specificity. Because of its lower detection threshold, LC/MS is able to measure a wider range of salivary T and F levels than other analytic methods. LC/MS, however, is expensive and requires specialized techniques.[44] It is thus not always a viable option. Finally, as our study period was rather short (within 72 hours after birth to 40 weeks' GA), future studies should confirm and explore associations between T and F levels and sociodemographic factors and the

Summary of Recommendations for Practice and Research

What we know:	• Black mothers and their VLBW, very preterm infants in the United States have increased risk of adverse birth outcomes and neonatal and maternal health outcomes compared with White mothers and infants. • Interventions to reduce the risk of adverse neonatal health and maternal mental health outcomes have yet to be effective in reducing disparities in these adverse outcomes. • Disparities in adverse birth outcomes are associated with sociodemographic factors, but the factors are difficult to quantify and modify, limiting their usefulness in assessing intervention effects.
What needs to be studies:	• The development of such interventions requires measurable, modifiable markers to serve as indicators of risk and intervention targets and to use in the assessment of intervention effects. • Identification of measurable, modifiable biological factors related to adverse neonatal health and maternal mental health outcomes in VLBW, very preterm birth would improve the identification of at-risk mothers and infants and the assessment of intervention effects. • Examine whether biological factors are associated with sociodemographic factors and both factors are associated with neonatal and maternal health outcomes.
What can we do today:	• Aim to show whether biological factors are associated with sociodemographic factors. • Aim to show whether biological factors are associated with neonatal birth outcomes, maternal mental health, and maternal healthy behaviors that are related to birth outcomes and mental health. • Aim to show whether sociodemographic factors are associated with neonatal birth outcomes, maternal mental health, and maternal healthy behaviors that are related to birth outcomes and mental health. • This approach could optimize our ability to reduce disparities in adverse pregnancy and birth outcomes, neonatal health, and maternal mental health and improve outcomes for high-risk mothers and their infants.

outcomes of neonatal health and maternal health beyond the immediate postnatal period.

CONCLUSION

In the present study, we identified high maternal T and low maternal F levels as potential biomarkers of adverse neonatal health and maternal mental health outcomes in VLBW, very preterm infants and their mothers between birth and 40 weeks' GA. Our findings also confirmed that disparities in birth outcomes in this high-risk population are associated with a complex interplay of social, economic, biological, and environmental factors. Biological and sociodemographic factors were associated with each other and also separately predicted various neonatal health and maternal health outcomes. We thus propose using sociodemographic and biological factors concurrently to identify risk and develop and evaluate ante- and postpartum interventions. This approach could optimize our ability to reduce disparities in adverse pregnancy and birth outcomes, neonatal health, and maternal mental health and improve outcomes for high-risk mothers and their infants.

References

1. March of Dimes Foundation. The cost of prematurity to employers. https://www.marchofdimes.org/mission/the-economic-and-societal-costs.aspx. Published 2019. Accessed on September 11, 2021.
2. Wormald F, Tapia JL, Torres G, et al. Stress in parents of very low birth weight preterm infants hospitalized in neonatal intensive care units. A multicenter study. *Arch Argent Pediatr*. 2015;113(4):303-309. doi:10.5546/aap.2015.331.
3. Martin JA, Hamilton BE, Osterman MJK, Driscoll AK, Drake P. Births: final data for 2016. *Natl Vital Stat Rep*. 2018;67(1):1-55.
4. Janevic T, Zeitlin J, Auger N, et al. Association of race/ethnicity with very preterm neonatal morbidities. *JAMA Pediatr*. 2018;172(11):1061-1069. doi:10.1001/jamapediatrics.2018.2029.
5. Amjad S, MacDonald I, Chambers T, et al. Social determinants of health and adverse maternal and birth outcomes in adolescent pregnancies: a systematic review and meta-analysis. *Paediatr Perinat Epidemiol*. 2019;33(1):88-99. doi:10.1111/ppe.12529.
6. Chambers BD, Baer RJ, McLemore MR, Jelliffe-Pawlowski LL. Using index of concentration at the extremes as indicators of structural racism to evaluate the association with preterm birth and infant mortality—California, 2011-2012. *J Urban Health*. 2019;96(2):159-170. doi:10.1007/s11524-018-0272-4.
7. Testa A, Jackson DB. Race, ethnicity, WIC participation, and infant health disparities in the United States. *Ann Epidemiol*. 2021;58:22-28. doi:10.1016/j.annepidem.2021.02.005.
8. Liese KL, Mogos M, Abboud S, Decocker K, Koch AR, Geller SE. Racial and ethnic disparities in severe maternal morbidity in the United States. *J Racial Ethn Health Disparities*. 2019;6(4):790-798. doi:10.1007/s40615-019-00577-w.
9. Giurgescu C, Misra DP. Psychosocial factors and preterm birth among Black mothers and fathers. *MCN Am J Matern Child Nurs*. 2018;43(5):245-251. doi:10.1097/NMC.0000000000000458.
10. Drake P, Driscoll AK, Mathews TJ. Cigarette smoking during pregnancy: United States, 2016. *NCHS Data Brief*. 2018;(305):1-8.
11. Tan CH, Denny CH, Cheal NE, Sniezek JE, Kanny D. Alcohol use and binge drinking among women of childbearing age—United States, 2011-2013. *MMWR Morb Mortal Wkly Rep*. 2015;64(37):1042-1046. doi:10.15585/mmwr.mm6437a3.
12. Cho J, Su X, Holditch-Davis D. Associations of hormonal biomarkers with mental health and healthy behaviors among mothers of very-low-birthweight infants. *Biol Res Nurs*. 2019;21(3):253-263. doi:10.1177/1099800419829592.
13. Galiatsatos P, Brigham E, Krasnoff R, et al. Association between neighborhood socioeconomic status, tobacco store density and smoking status in pregnant women in an urban area. *Prev Med*. 2020;136:106107. doi:10.1016/j.ypmed.2020.106107.
14. Melnyk BM, Gennaro S, Szalacha LA, et al. Randomized controlled trial of the COPE-P intervention to improve mental health, healthy lifestyle behaviors, birth and post-natal outcomes of minority pregnant women: study protocol with implications. *Contemp Clin Trials*. 2020;98:106090. doi:10.1016/j.cct.2020.106090.
15. Barrett ES, Mbowe O, Thurston SW, et al. Predictors of steroid hormone concentrations in early pregnancy: results from a multi-center cohort. *Matern Child Health J*. 2019;23(3):397-407. doi:10.1007/s10995-018-02705-0.
16. Klevedal C, Turkmen S. Fetal-maternal outcomes and complications in pregnant women with polycystic ovary syndrome. *Minerva Ginecol*. 2017;69(2):141-149. doi:10.23736/S0026-4784.16.03946-0.
17. Lorch SA, Enlow E. The role of social determinants in explaining racial/ethnic disparities in perinatal outcomes. *Pediatr Res*. 2016;79(1/2):141-147. doi:10.1038/pr.2015.199.
18. Brazy JE, Eckerman CO, Oehler JM, Goldstein RF, O'Rand AM. Nursery Neurobiologic Risk Score: important factor in predicting outcome in very low birth weight infants. *J Pediatr*. 1991;118(5):783-792. doi:10.1016/s0022-3476(05)80047-2.
19. Radloff LS. The CES-D Scale: a self-report depression scale for research in the general population. *Appl Psychol Meas*. 1977;1(3):385-401. doi:10.1177/014662167700100306.
20. Andreou E, Alexopoulos EC, Lionis C, et al. Perceived Stress Scale: reliability and validity study in Greece. *Int J Environ Res Public Health*. 2011;8(8):3287-3298. doi:10.3390/ijerph8083287.
21. Marteau TM, Bekker H. The development of a six-item short-form of the state scale of the Spielberger State–Trait Anxiety Inventory (STAI). *Br J Clin Psychol*. 1992;31(3):301-306. doi:10.1111/j.2044-8260.1992.tb00997.x.
22. Kim S, Popkin BM, Siega-Riz AM, Haines PS, Arab L. A cross-national comparison of lifestyle between China and the United States, using a comprehensive cross-national measurement tool of the healthfulness of lifestyles: the Lifestyle Index. *Prev Med*. 2004;38(2):160-171. doi:10.1016/j.ypmed.2003.09.028.
23. NIH Consensus Development Panel. Effect of corticosteroids for fetal maturation on perinatal outcomes. *JAMA*. 1995;273(5):413-418. doi:10.1001/jama.1995.03520290065031.
24. Buttler RM, Bagci E, Brand HS, Heijer MD, Blankenstein MA, Heijboer AC. Testosterone, androstenedione, cortisol and cortisone levels in human unstimulated, stimulated and parotid saliva. *Steroids*. 2018;138:26-34. doi:10.1016/j.steroids.2018.05.013.
25. Svensson K, Just AC, Fleisch AF, et al. Prenatal salivary sex hormone levels and birth-weight-for-gestational age. *J Perinatol*. 2019;39(7):941-948. doi:10.1038/s41372-019-0385-y.
26. James WH. Hypothesis: high levels of maternal adrenal androgens are a major cause of miscarriage and other forms of reproductive suboptimality. *J Theor Biol*. 2015;364:316-320. doi:10.1016/j.jtbi.2014.09.027.
27. Morisset AS, Dube MC, Drolet R, et al. Androgens in the maternal and fetal circulation: association with insulin resistance. *J Matern Fetal Neonatal Med*. 2013;26(5):513-519. doi:10.3109/14767058.2012.735725.
28. Gillespie SL, Mitchell AM, Kowalsky JM, Christian LM. Maternal parity and perinatal cortisol adaptation: the role of pregnancy-specific distress and implications for postpartum mood. *Psychoneuroendocrinology*. 2018;97:86-93. doi:10.1016/j.psyneuen.2018.07.008.
29. Simon CD, Adam EK, Holl JL, Wolfe KA, Grobman WA, Borders AE. Prenatal stress and the cortisol awakening response in African-American and Caucasian women in the third trimester of pregnancy. *Matern Child Health J*. 2016;20(10):2142-2149. doi:10.1007/s10995-016-2060-7.
30. Duffy AR, Schminkey DL, Groer MW, Shelton M, Dutra S. Comparison of hair cortisol levels and perceived stress in mothers who deliver at preterm and term. *Biol Res Nurs*. 2018;20(3):292-299. doi:10.1177/1099800418758952.
31. Braithwaite EC, Hill J, Pickles A, Glover V, O'Donnell K, Sharp H. Associations between maternal prenatal cortisol and fetal growth are specific to infant sex: findings from the Wirral Child Health and Development Study. *J Dev Orig Health Dis*. 2018;9(4):425-431. doi:10.1017/S2040174418000181.
32. Caparros-Gonzalez RA, Romero-Gonzalez B, Gonzalez-Perez R, et al. Maternal and neonatal hair cortisol levels are associated with infant neurodevelopment at six months of age. *J Clin Med*. 2019;8(11):2015. doi:10.3390/jcm8112015.
33. Conradt E, Shakiba N, Ostlund B, et al. Prenatal maternal hair cortisol concentrations are related to maternal prenatal emotion dysregulation but not neurodevelopmental or birth outcomes. *Dev Psychobiol*. 2020;62(6):758-767. doi:10.1002/dev.21952.
34. Caparros-Gonzalez RA, Romero-Gonzalez B, Strivens-Vilchez H, Gonzalez-Perez R, Martinez-Augustin O, Peralta-Ramirez MI. Hair cortisol levels, psychological stress and psychopathological symptoms as predictors of postpartum depression. *PLoS One*. 2017;12(8):e0182817. doi:10.1371/journal.pone.0182817.
35. Scheyer K, Urizar GG Jr. Altered stress patterns and increased risk for postpartum depression among low-income pregnant women. *Arch Womens Ment Health*. 2016;19(2):317-328. doi:10.1007/s00737-015-0563-7.
36. Seth S, Lewis AJ, Galbally M. Perinatal maternal depression and cortisol function in pregnancy and the postpartum period: a systematic literature review. *BMC Pregnancy Childbirth*. 2016;16(1):124. doi:10.1186/s12884-016-0915-y.
37. Griggs KM, Hrelic DA, Williams N, McEwen-Campbell M, Cypher R. Preterm labor and birth: a clinical review. *MCN Am J Matern Child Nurs*. 2020;45(6):328-337. doi:10.1097/NMC.0000000000000656.
38. Manuck TA. Racial and ethnic differences in preterm birth: a complex, multifactorial problem. *Semin Perinatol*. 2017;41(8):511-518. doi:10.1053/j.semperi.2017.08.010.
39. Black AP, Brimblecombe J, Eyles H, Morris P, Vally H, O'Dea K. Food subsidy programs and the health and nutritional status of disadvantaged families in high income countries: a systematic review. *BMC Public Health*. 2012;12:1099. doi:10.1186/1471-2458-12-1099.
40. Shapiro GD, Bushnik T, Wilkins R, et al. Adverse birth outcomes in relation to maternal marital and cohabitation status in Canada. *Ann Epidemiol*. 2018;28(8):503-509.e11. doi:10.1016/j.annepidem.2018.05.001.
41. Sullivan K, Raley RK, Hummer RA, Schiefelbein E. The potential contribution of marital-cohabitation status to racial, ethnic, and nativity differentials in birth outcomes in Texas. *Matern Child Health J*. 2012;16(4):775-484. doi:10.1007/s10995-011-0801-1.
42. Tarca AL, Romero R, Gudicha DW, et al. A new customized fetal growth standard for African American women: the PRB/NICHD Detroit study. *Am J Obstet Gynecol*. 2018;218(2S):S679-S691.e4. doi:10.1016/j.ajog.2017.12.229.
43. Olendzki B, Procter-Gray E, Magee MF, et al. Racial differences in misclassification of healthy eating based on Food Frequency Questionnaire and 24-hour dietary recalls. *J Nutr Health Aging*. 2017;21(7):787-798. doi:10.1007/s12603-016-0839-2.
44. Welker KM, Lassetter B, Brandes CM, Prasad S, Koop DR, Mehta PH. A comparison of salivary testosterone measurement using immunoassays and tandem mass spectrometry. *Psychoneuroendocrinology*. 2016;71:180-188. doi:10.1016/j.psyneuen.2016.05.022.