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Original Research Article

Maternal Childhood Adversity as a Risk for Perinatal Complications and NICU Hospitalization

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Abstract

Objective To examine maternal childhood adversity in relation to increased risk for maternal and infant perinatal complications and newborn Neonatal Intensive Care Unit (NICU) admittance. **Methods** A sample of 164 women recruited at their first prenatal appointment participated in a longitudinal study through 6 weeks postdelivery. Participants self-reported on their adverse childhood experiences (ACEs), negative health risks (overweight/obesity, smoking, and alcohol use), adverse infant outcomes, NICU admittance, and maternal perinatal complications across three pregnancy assessments and one post-birth assessment. Logistic binomial regression analyses were used to examine associations between maternal ACEs and adverse infant outcomes, NICU admittance, and maternal perinatal complications, controlling for pregnancy-related health risks. **Results** Findings showed that women with severe ACEs exposure (6+ ACEs) had 4 times the odds of reporting at least one adverse infant outcome (odds ratio [OR] = 4.33, 95% CI: 1.02–18.39), almost 9 times the odds of reporting a NICU admission (OR = 8.70, 95% CI: 1.34–56.65), and 4 times the odds of reporting at least one maternal perinatal outcome (OR = 4.37, 95% CI: 1.43–13.39). **Conclusions** The findings demonstrate the extraordinary risk that mothers' ACEs pose for infant and maternal health outcomes over and above the associations with known maternal health risks during pregnancy, including overweight/obesity, smoking, and alcohol use. These results support a biological intergenerational transmission framework, which suggests that risk from maternal adversity is perpetuated in the next generation through biophysical and behavioral mechanisms during pregnancy that negatively affect infant health outcomes.

Key words: early life adversity; Neonatal intensive care unit (NICU); prematurity and low birthweight; health risk behavior; sexual or reproductive health.

Introduction

Although advances in obstetric and neonatal medicine and the expansion of neonatal intensive care units (NICUs) have contributed to significant decreases in neonatal mortality and severe morbidity (Ancel et al., 2015; Manuck et al., 2016; Stephens et al., 2008), perinatal complications, particularly those resulting in a NICU admission, remain a serious public health concern. NICU admission at any gestational age relative to the effects of prematurity or other birth injuries/complications has been associated with adverse neurodevelopmental outcomes that may persist into

childhood and adulthood (Moster et al., 2008; American College of Obstetricians and Gynecologists and Task Force on Hypertension in Pregnancy, 2013).

Although there is significant regional and interhospital variation in reported admission rates (Braun et al., 2020; Harrison et al., 2018), NICU admissions have shown steep increases over time, with a 69% increase in overall NICU admissions between 1995 and 2013 (Goodman et al., 2019). In 2013, 7.2% (237,311 live births) of all newborns were admitted to higher level NICUs (Levels III and IV) (Harrison et al., 2018) and the March of Dimes (2011) reported that 14.4% of newborns born in 2009–2010 were admitted to Level II or Level III special care nurseries/NICUs. Notably, infants born full term and of normal birth weight (2,500–3,999g) are increasingly likely to be admitted to the NICU, representing more than half of all admitted newborns (Harrison & Goodman, 2015; March of Dimes, 2011; Moen et al., 2017), and fewer than 20% of NICU admissions are considered high illness acuity (Schulman et al., 2018). The most common diagnoses listed for NICU admissions include preterm birth (23.6%), respiratory distress syndrome (11.9%), newborn septicemia (4.0%), and transitory tachypnea of newborn (3.9%; March of Dimes, 2011). Interestingly, 10% of infants born at 37–41 weeks had no first-associated diagnoses at NICU admission (March of Dimes, 2011). Still, these infants remain at increased risk for short- and long-term medical complications and neurodevelopmental impairments (Baron et al., 2012; Boyle et al., 2012), and there are significant financial and psychosocial costs associated with the ongoing medical, educational, and social needs of NICU graduates (Muraskas & Parsi, 2008). As a result, it is imperative to identify and examine risk factors for adverse birth outcomes.

Maternal health and perinatal complications during pregnancy and delivery are well-known risk factors for neonatal morbidities and NICU hospitalization. Preterm premature rupture of the membranes is one of the most common obstetric complications, affecting as many as 34.4% of pregnancies associated with preterm birth and NICU hospitalization (Linehan et al., 2016; Manuck et al., 2016). Other common obstetric complications among NICU admissions include breech presentation, chorioamnionitis, cervical cerclage, abruption, placenta previa, and maternal hypertension (Manuck et al., 2016). Infants born with low birthweight or small for gestational age are often small due to preterm delivery or due to fetal growth problems that occur during pregnancy, commonly intrauterine growth restriction (IUGR; Sharma et al., 2016). Importantly, adverse pregnancy and birth complications are highly comorbid, and risks for preterm birth and low birthweight increase with the incidence of other pregnancy and birth complications, including IUGR, maternal cardiovascular disease, pregnancy-induced hypertension/preeclampsia, gestational diabetes, infection, and placental complications, as well as malnutrition, substance use, and multiple gestation (Ciciolla et al., 2019). Although many perinatal complications can occur spontaneously without previously known health vulnerabilities (Souza et al., 2020), there is evidence that maternal preconception health, including psychosocial health, are associated with significantly increased risk for perinatal complications for women and their infants (Robbins et al., 2014).

Decades of research on exposure to adverse childhood experiences (ACEs), which includes traumatic experiences like abuse and neglect, domestic violence, and substance use by caregivers, reveals a strong association with poor health outcomes in adulthood following a dose response pattern. That is, the likelihood of poor health outcomes increases with the number of ACEs experienced (Felitti et al., 1998; Gilbert, 2015). There is increasing evidence that exposure to ACEs is associated with adverse perinatal outcomes, including maternal prenatal health risks, such as hypertension, diabetes, overweight/obesity, and alcohol use (Frankenberger et al., 2015; Madigan et al., 2017; Racine et al., 2018a; Roberts et al., 2013), as well as preterm birth and low birthweight infants (Christiaens et al., 2015; Mersky & Lee, 2019; Smith et al., 2016).

Several theoretical models describe biological and psychosocial pathways through which early maternal adversity contributes to intergenerational transmission of risk for adverse birth outcomes, including allostatic load and early programming (Beckie, 2012; McEwen, 1998; Olson et al., 2015). Increased allostatic load, or cumulative physiological damage, is associated with increased disease burden and is considered a primary mechanism for many stress-related chronic disorders, including hypertension and cardiovascular disease, diabetes, and metabolic syndrome (Geronimus 2001; Geronimus et al., 2010; Giurgescu et al., 2013; Wallace & Harville, 2013). These maternal chronic disorders are the largest predictors for both maternal and infant morbidity and mortality (Centers for Disease Control [CDC], 2017; Gavin et al., 2012). Thus, maternal biological risk associated with adverse maternal and infant perinatal outcomes may be exacerbated following exposure to adversity.

Notably, there has been much emphasis on the social determinants of health and racial/ethnic disparities in maternal and infant morbidity and mortality (Keating et al., 2020). Non-Hispanic Black Americans and American Indians/Alaska Natives are disproportionately affected by almost every perinatal complication compared with other racial groups, as well as the highest rates of maternal and infant mortality (Ciciolla et al., 2019). Racial disparities in perinatal outcomes are robust, consistent across time and

complication type, and tend to cluster with other personal, social, and environmental risk factors, including unequal access to quality health care and education; disproportionate exposure to health hazards like ACEs, inadequate housing, poor nutrition, and community violence (Braveman, 2014; Chae et al., 2011); and psychosocial stress associated with chronic exposure to racism and discrimination (Christian et al., 2013; Collins et al., 2004).

These disproportionate patterns of disease incidence suggest that there may be shared pathogenic biological mechanisms underlying disparities in adverse pregnancy and birth outcomes (Anachebe & Sutton, 2003) that can be linked to high allostatic load and inflammatory reactivity (i.e., "weathering," or wear and tear on their health; Geronimu, 2001; Geronimus et al., 2006) associated with disproportionate exposure to psychosocial stress and adversity (e.g., ACEs, racism; Collins et al., 2004; Lu et al., 2019; Geronimus et al., 2010). It is critical, therefore, to consider racial/ethnic associations with perinatal complications and adverse birth outcomes.

Maternal childhood adversity is also linked to health risk behaviors, such as substance abuse, that heighten perinatal risks during pregnancy. For example, Chung et al. (2010) reported the odds of smoking or the use of alcohol, marijuana, and other illicit drugs during pregnancy was 2.5 times greater for women with three or more ACEs. These behaviors during pregnancy have been associated with increased risk of adverse birth outcomes (Anderson et al., 2006; Robbins et al., 2014). This suggests that health risk behaviors and their associated biological and physiological impacts may be another pathway that links maternal childhood adversity with adverse perinatal outcomes.

No known study to date has examined the probability of a NICU hospitalization in relation to maternal ACE score, and few studies have prospective pregnancy data to examine the association between ACEs and obstetric complications during pregnancy and childbirth. To address this gap in the literature, the current study uses prospective, longitudinal, and mixed methods data to test the associations between maternal ACEs, and the risk for adverse infant outcomes, NICU hospitalization, and maternal perinatal complications, accounting for maternal health risk and health risk behaviors including tobacco and alcohol use and overweight/obesity. It was hypothesized that women with a higher number of ACEs would have an increased probability of infant and maternal perinatal complications, including NICU hospitalization.

Materials and Methods

Sample

Data were collected from a prospective sample of 177 pregnant women (ages 16–39) recruited in 2017–2018 from two community OB-GYN clinics in a small metropolitan city serving diverse, low-income populations. The clinics are affiliated with the two public medical universities in the city and because they are located on opposite sides of the city, are able to serve the majority of residents on public insurance. The OB-GYN providers, including physicians and nurse midwives, deliver at all hospitals across the city. In addition to prenatal services, the OB-GYN clinics provide a wide range of women's health services. Both clinics offer behavioral health services on a part-time basis from social workers, and both universities offer psychiatric services on-site, which allows for the streamlining of referrals. The overall clinic populations—including all patients, not only pregnant women—are more diverse than the city as a whole by race/ethnicity (~50% White; 10% Hispanic; 30% Black, and 10% American Indian/Alaska Native) but are predominately low income. The sample recruited for the current study is more diverse than the overall clinic population (~41% White; 12% Hispanic; 29% Black, and 16% American Indian/Alaska Native), likely due to the younger ages of women seeking prenatal services, reflecting demographic changes in race/ethnicity by age in the state. We restricted our sample to 164 participants with available data on ACEs for our analyses, which were collected at the first prenatal visit. Mean and chi squared comparisons of baseline data indicated that the participants without available ACEs data ($N = 13$) were statistically significantly younger (21.5 vs. 25.4 years; $t = 2.04$, $p < .05$), but did not otherwise differ on demographic or key study variables, including race, overweight status, health complications (hypertension and diabetes), or health risk behavior (drinking and smoking).

Attrition was greatest between the first and second trimester; the majority of known reasons for attrition were due to pregnancy loss. Nearly three-quarters (73%) of participants who enrolled in the study continued their participation through the 6-week postbirth survey; this response rate is comparable with other cohort studies of low income and diverse populations (Nicholson et al., 2015). Birth outcome data were collected from 124 participants. Mean and chi squared comparisons of baseline data indicated that the participants lost to attrition ($N = 40$) were statistically significantly younger (23.9 vs. 25.9 years), but did not otherwise differ on demographic or key study variables, including race, ACEs, overweight status, health complications (hypertension and diabetes), or health risk behavior (drinking and smoking).

Procedure

Informed consent procedures and enrollment were done in person at recruitment during the first prenatal visit. Participants were compensated $50 for

participation in the first assessment, and $40 for each subsequently completed survey (electronic). All recruitment and study procedures were approved by the University and Hospital IRBs.

For recruitment, clinic nursing staff introduced the study to potential participants and those interested in learning more about the study were transferred to research project staff members for informed consent and enrollment procedures. Signed informed consent (or signed informed assent and parental informed consent in cases where participants were minors) was obtained before study procedures began.

At enrollment, women provided demographic information and reported their exposure to ACEs, provided height and weight data to calculate body mass index (BMI), and provided a saliva sample that was used to determine cotinine levels as a marker of tobacco use. Saliva samples were collected by research staff members and processed and stored within 1 hr. Cotinine, the primary metabolite of nicotine, was assayed with ELISA by staff scientists at an immunology research lab at one of the clinic site locations. Women were contacted via cellphone texts and emails with links to additional online surveys in each trimester of pregnancy and 6 weeks after childbirth, for a total of four assessments during the study period reported here. Tablets were available at the clinics for participants who did not have access to smart phones or computers, though no participants opted to use the clinic tablets after the first survey. The surveys asked participants to report on health risk behaviors during pregnancy, including tobacco and alcohol use, pregnancy complications, birth complications, and NICU admissions. Participants were compensated within 24 hr of completing a survey assessment using ClinCards (i.e., reloadable debit cards), which enhanced participant response rates. Women self-reported about their pregnancy and birth experiences in the postbirth survey, and ~10% of survey responses were verified by data abstracted from the electronic medical record (EMR; abstraction is ongoing at both sites). EMR data were abstracted by medical residents who did not have access to the survey data and imported into the study RedCAP database by the university's RedCAP support staff director per IRB protocol.

Measures

Measures of childhood adversity, maternal health risks, and participant demographic characteristics were assessed in the first online survey following participant consent procedures, and outcomes of interest (NICU admission and perinatal complications) were assessed following childbirth using survey responses to the 6-week post-birth survey.

Childhood adversity was assessed using the ACE Scale, which asked participants whether they experienced 10 types of adverse experiences classified as abuse, neglect, or household dysfunction, prior to age 18 years of age (Dong et al., 2004; Felitti et al., 1998). Preliminary analyses suggested a cubic association between ACEs and adverse birth outcomes. Notably, participants reporting a NICU hospitalization had ACE scores falling in only 2 of the traditional ACEs categories (i.e., 0, 1, 2, 3, and 4+ ACEs, Dong et al., 2004; Felitti et al., 1998): 9 participants reported zero ACEs and 10 participants reported 4 or more ACEs, 6 of whom had scores >5. Additionally, the relatively small sample size of this study ($N = 164$) and low frequency of adverse perinatal outcomes (e.g., rates of US NICU admissions: 7.8–12%; see Braun et al., 2020; Haidari et al., 2021) resulted in small cell sizes when using the traditional categorization method (Dong et al., 2004; Felitti et al., 1998). As such, participants' ACE scores were coded into three categories, similar to the strategies used by Youssef et al. (2017) and Brown et al. (2009): low = 0–2 ACEs; moderate = 3–5 ACEs; and high = 6+ ACEs.

Measures of maternal health risks were assessed at the first prenatal appointment following participant consent procedures. Age was assessed as a continuous variable and ranged from 16 to 38. Overweight was calculated based on participants' weight and height, following the National Health and Examination Survey guidelines (see Fryar et al., 2012), with BMI scores of 25 or above = 1, and under 25 = 0. Smoking status at the first prenatal visit was calculated based on participants' cotinine values using the standard cutoff values (Kim, 2016). Cotinine values below 10 ng/ml were coded as 0 indicating nonsmoking, and values of 10 ng/ml and above were coded as 1, indicating smoking. Self-reports of smoking tobacco during pregnancy were assessed at each of the pregnancy assessments and following birth. Participants who reported smoking following pregnancy confirmation at any of the prenatal assessments were coded as 1; and participants who reported not smoking following pregnancy confirmation were coded as 0. Self-reported alcohol use during pregnancy was assessed at each of the pregnancy assessments and following birth. Participants who reported using alcohol following pregnancy confirmation at any of the prenatal assessments were coded as 1; and participants who reported no alcohol use following pregnancy confirmation were coded as 0.

A number of infant and maternal health complications were reported in the data across pregnancy assessments and following birth (see Table I for types, frequencies, and percentages of adverse infant and maternal outcomes). These data were self-reported, and a proportion of 10% were verified from data abstracted from the medical record. For data analyses, adverse infant outcome, coded yes (1) or no (0), included the occurrence of at

Table I. *Descriptive Statistics of Maternal Perinatal Complications and Adverse Infant Outcomes*

	N	%	*M*	SD	Range
Maternal perinatal complication ($N = 164$)	56	34.1			
High blood pressure	24	14.6			
Gestational diabetes	10	6.1			
Other perinatal complication	10	6.1			
Emergency Cesarean section	18	11.0			
Perinatal loss (miscarriage and stillbirth)	10	6.1			
Adverse birth outcome ($N = 124$)	36	29.0			
Prematurity (≤37 weeks)	22	13.4			
Gestational age (weeks)[a]			35.33	1.78	32–37
Low birthweight (<2,500 g)	16	9.8			
Very low birthweight (<1,500 g)	2	1.2			
Birthweight (g)[b]			2044.35	469.94	595.34–2,460.74
NICU hospitalization	19	15.4			
Reasons for NICU hospitalization ($N = 19$)					
Hypoglycemia	3	15.8			
Preterm birth	4	21.1			
Breathing problems	4	21.1			
Other reason	8	42.1			

Note. All variables coded as yes/no (1/0) unless specified otherwise.
[a]Calculated for all infants classified as premature.
[b]Calculated for all infants classified as low/very low birthweight. Other perinatal complication included prenatal bleeding, postpartum hemorrhage, pain, blood clot, and infection. Other reason for NICU hospitalization included neonatal abstinence syndrome, aspiration, infection, fever, and congenital disorder.

least one infant health complication, including prematurity (≤37 weeks), low birthweight (<2,500 g), or NICU hospitalization. NICU hospitalization was also examined as a stand-alone outcome variable, coded yes (1) or no (0). Maternal perinatal complication, coded yes (1) or no (0), included the occurrence of at least one pregnancy or birth complication, including gestational diabetes, hypertension, perinatal loss (miscarriage, stillbirth), emergency Cesarean section, or other perinatal complication. Other perinatal complication included prenatal bleeding, postpartum hemorrhage, pain, blood clot, and infection.

Results

Descriptive statistics for the full sample are presented in Table II, along with descriptives according to ACE exposure.

Logistic regression analyses were used to describe the strength of the association between adverse infant outcome, NICU hospitalization, and maternal perinatal complication as a function of exposure to low (0–2), moderate (3–5), and high ACES (6+), with low ACEs being the reference group for all comparisons. Results for adverse infant outcome and NICU hospitalization are reported in Table III, and results for maternal perinatal complications are reported in Table IV. All analyses included age, race, BMI score at first prenatal visit, cotinine levels at first prenatal visit, self-reported smoking during pregnancy, and self-reported alcohol use during pregnancy as covariates. Models for adverse infant outcome and NICU hospitalization additionally controlled for occurrence of maternal hypertension and gestational diabetes.

Women with high ACEs had 4 times the odds of reporting an adverse infant outcome, odds ratio (OR) = 4.33, 95% CI: 1.02–18.39, and almost 9 times the odds of a NICU hospitalization, OR = 8.7, 95% CI: 1.34–56.65, respectively. Similarly, women with high ACEs had 4 times the odds of reporting a perinatal complication, OR = 4.37, 95% CI: 1.43–13.39. Self-reported alcohol use was associated with increased odds of reporting an adverse infant outcome, OR = 9.51, 95% CI: 1.73–52.44, or a NICU hospitalization, OR = 8.87, 95% CI: 1.38–57.01, respectively, and gestational diabetes was associated with an increased risk for a NICU hospitalization, OR = 14.69, 95% CI: 1.40–54.33. The risk of maternal perinatal complication increased by ∼8% with each 1-point increase in BMI, OR = 1.08, 95% CI: 1.02–1.13. Although not statistically significant, Black, Hispanic, and American Indian/Alaska Native racial identities (compared with White racial identity), as well as cotinine exposure early in pregnancy, were associated with elevated ORs for adverse infant outcomes, and maternal complications.

Discussion

This study is the first to examine the association between maternal ACEs and adverse infant outcomes, NICU admission, and maternal perinatal complications. The results of this study indicate that mothers' ACE scores pose a significant risk for infant health

Table II. *Sample Demographics and Frequency of Perinatal Complications According to Exposure to Adverse Childhood Experiences (ACEs)*

	Low ACEs ($n = 92$, 56.1%) *M* (SD) or % (N)	Moderate ACEs ($n = 43$, 26.2%) *M* (SD) or % (*N*)	High ACEs ($n = 29$, 17.7%) *M* (SD) or % (*N*)	Total sample ($n = 164$) *M* (SD) or % (*N*)
Age (years)	25.27 (5.4)	26 (5.24)	25.21 (6.59)	25.45 (5.58)
BMI score	30.24 (8.15)	30.87 (9.60)	28.95 (6.82)	30.16 (8.31)
Overweight (BMI > 25)[a]	40.5 (32)	50 (19)	44.4 (12)	38.4 (63)
Race = Black	38.5 (35)	25.6 (11)	6.9 (2)	29.3 (48)
Race = AI/AN	16.7 (15)	11.6 (5)	24.1 (7)	16.5 (27)
Race = Hispanic	9.9 (9)	20.9 (9)	6.9 (2)	12.2 (20)
Race = White	34.1 (31)	18 (41.9)	62.1 (18)	40.9 (67)
Cotinine confirmed smoking[a]	60.5 (32)	54.3 (16)	53.8 (14)	50.0 (82)
Self-reported smoking	30 (27)	41.9 (18)	37.9 (11)	34.1 (56)
Self-reported alcohol use	12.1 (11)	23.3 (10)	13.8 (4)	15.2 (25)
Adverse infant outcome	29.6 (21)	16.1 (5)	45.5 (10)	22 (36)
Prematurity (≤37 weeks)	21.1 (15)	9.7 (3)	18.2 (4)	13.4 (22)
Gestational age (weeks)	39.86 (2.08)	40.44 (1.85)	39.05 (3.47)	39.85 (2.36)
Low birthweight (<2,500 g)	17.7 (11)	3.6 (1)	20 (4)	9.8 (16)
Birthweight (g)	3,064.15 (607.32)	3,325.79 (558.73)	3,152.19 (625.79)	3,146.93 (603.66)
NICU hospitalization	14.3 (9)	13.8 (4)	30 (6)	11.6 (19)
Maternal perinatal complication	29.3 (27)	34.9 (15)	48.3 (14)	34.1 (56)
Gestational diabetes	6.5 (6)	0.6 (1)	1.8 (3)	6.1 (10)
Hypertension	9.8 (9)	18.6 (8)	24.1 (7)	14.6 (24)
Perinatal loss	5.4 (5)	4.7 (2)	10.3 (3)	6.1 (10)
Emergency Cesarean section	15.3 (11)	12.5 (4)	13.6 (3)	11.0 (18)

Note. AI/AN = American Indian/Alaskan Native. $N = 164$. All variables coded as yes/no (1/0) unless specified otherwise. Low ACEs = 0–2; moderate ACEs = 3–5; and high ACEs = 6+. Smoking, alcohol use, gestational diabetes, and hypertension were self-reported across pregnancy. Cotinine levels assayed from saliva. Adverse infant outcomes included prematurity, low birthweight, and NICU hospitalization. Maternal perinatal complications included gestational diabetes, hypertension, other perinatal complication, perinatal loss (miscarriage, stillbirth), and emergency Cesarean section. Other perinatal complication included prenatal bleeding, postpartum hemorrhage, pain, blood clot, and infection.

[a]Assessed at first prenatal visit.

outcomes, over and above the associations with known maternal health risks during pregnancy, including overweight/obesity, smoking, and alcohol use. Women reporting six or more ACEs had 4 times greater odds of having an infant with adverse birth outcomes, almost 9 times greater odds of having an infant hospitalized in the NICU, and 4 times greater odds of having any pregnancy or birth complications, supporting our hypotheses. Overall, these findings are consistent with previous research showing that women with higher ACE scores were more likely to have perinatal complications including preterm birth and infants with low birthweights (Christiaens et al., 2015; Mersky & Lee, 2019; Smith et al., 2016), as well as maternal health risks during pregnancy (Frankenberger et al., 2015; Madigan et al., 2017; Racine et al., 2018a; Roberts et al., 2013).

Our results support a biological intergenerational transmission framework, which suggests that risk from maternal childhood adversity may be perpetuated in the next generation through biophysical and behavioral mechanisms during pregnancy that negatively affect infant health outcomes (Buss et al., 2017; Racine et al., 2018b). Pregnancy and childbirth present a special and extreme physiological challenge that may activate underlying predispositions to systemic inflammation and disease especially when combined with external stress exposure, helping to explain the incidence of gestational, new-onset diseases like hypertension or diabetes among seemingly healthy women, as well as the increased risk for long-term maternal morbidity postpregnancy and adverse health outcomes in offspring (Cheong et al., 2016). Notably, adverse birth outcomes like preterm birth or low birthweight may predispose offspring to develop health problems in adulthood, including cardiovascular disease and diabetes, which has clear implications for future perinatal risk in the next generation (Pinheiro et al., 2016). In addition, the psychosocial stress of childhood adversity is associated with maladaptive coping behaviors such as overeating and abusing substances including alcohol, nicotine, and illicit substances (Duffy et al., 2018).

Although not statistically significant (likely due to the small sample size resulting in large standard errors), the findings also suggest a 25–250% increased likelihood for adverse infant outcomes, NICU hospitalization, and maternal perinatal complications among Black, Hispanic, and American Indian/Alaska Native women compared with White women, despite similar health risk exposures (e.g., ACEs, overweight/obesity, smoking, alcohol use). Using a biological

Table III. *Logistic Regression Analysis of Adverse Infant Outcome (Yes/No) and Neonatal Intensive Care Unit (NICU) Hospitalization (Yes/No) By Exposure to Adverse Childhood Experiences (ACEs)*

Predictors	Adverse infant outcome ($n = 91$)					NICU hospitalization ($n = 83$)				
	B	SE	OR	95% CLs		*B*	SE	OR	95% CLs	
				Lower	Upper				Lower	Upper
Constant	−5.82**	2.01	0.00	—	—	−5.98*	2.44	0.00	—	—
Age (years)	0.12*	0.05	1.13	1.01	1.25	0.10	0.06	1.11	.98	1.25
Race = Black	0.95	0.72	2.58	0.63	10.54	0.90	0.87	2.45	0.44	13.57
Race = AI/AN	0.39	0.84	1.48	0.28	7.74	0.25	1.01	1.29	0.18	9.37
Race = Hispanic	1.65	1.14	5.20	0.56	48.56	—	—	—	—	—
Race = White, ref	—	—	—	—	—	—	—	—	—	—
BMI score[a]	0.01	0.03	1.01	.94	1.07	−0.02	0.05	0.98	0.89	1.08
Cotinine confirmed smoking[a]	1.18	0.77	3.26	0.71	14.84	1.12	0.96	3.07	0.47	20.21
Self-reported smoking	0.40	0.70	1.49	0.38	5.83	−0.09	0.91	0.92	0.15	5.46
Self-reported alcohol use	2.25**	0.87	9.51	1.73	52.44	2.18*	0.95	8.87	1.38	57.01
Gestational diabetes	0.93	0.99	2.55	0.37	17.72	2.69*	1.2	14.69	1.40	54.33
Hypertension	−0.96	0.82	0.38	0.08	1.92	−1.30	1.09	0.27	0.03	2.33
0–2 ACEs, ref	—	—	—	—	—	—	—	—	—	—
3–5 ACEs	−0.95	0.79	0.38	0.08	1.79	0.44	0.95	1.55	0.24	9.91
6+ ACEs	1.47*	0.79	4.33	1.02	18.39	2.16*	0.96	8.70	1.34	56.65

Note. OR = odds ratio. CL = confidence limit. AI/AN = American Indian/Alaska Native. All variables coded as yes/no (1/0) unless specified otherwise. No participants identifying as Hispanic had a NICU hospitalization. Adverse infant outcomes included prematurity (≤37 weeks), low birthweight (<2,500 g), and NICU hospitalization. Smoking, alcohol use, gestational diabetes, and hypertension were self-reported across pregnancy. Cotinine levels were assayed from saliva.

[a]Assessed at first prenatal visit.

*$p < .05$;

**$p < .01$.

intergenerational transmission framework to conceptualize the risk for adverse perinatal outcomes, it is crucial to consider the association of high allostatic load, inflammatory reactivity, and biological "weathering" to the disproportionate exposure to stress according to racial identity, including exposure to racism (Collins et al., 2004; Geronimus et al., 2010). In addition to disruptions in the uterine environment related to maternal health risks and complications (Hocher, 2014), other research has suggested that the combination of adverse developmental environments or early childhood exposure to psychosocial stress, like ACEs and racism, are linked to epigenetic changes that alter physiological function and contribute to generational disease risk (Bick et al., 2012; Brockie et al., 2013; Lu et al., 2019). Thus, differential exposure to biological and social stressors may be a key factor underlying the processes of physiological adaptation and differential health trajectories, and may be a primary source for disparities among racial groups (Cheong et al., 2016; Ciciolla et al., 2019).

Birth complications resulting in a NICU hospitalization significantly increase the risk for adverse neurodevelopmental outcomes, and there is evidence that neonatal morbidities may be associated with long-term medical and social impairments that persist into childhood and adulthood (Baron et al., 2012; Moster et al., 2008; Smith et al., 2016). Even if the reason for hospitalization is minor, the NICU hospitalization itself can increase the risk for long-term morbidity in association with separation from caregivers, disruptions in bonding, and overwhelming sensory input that may disrupt neurobiological development and affect stress regulation (Sanders & Hall, 2018). Moreover, the stress of NICU hospitalization on caregivers can increase the risk for parental psychopathology and disrupt parental engagement and sensitive parenting behaviors (Lean et al., 2018), which can contribute to or exacerbate neurodevelopmental and psychosocial impairments in infants and children.

Notably, the findings suggest a threshold-effect, with the association between maternal ACEs and adverse perinatal outcomes clustering at the highest levels of adversity. That is, when considering relatively infrequent events or events that have a strong associations with genetic, congenital, or other infectious factors (i.e., not adversity related), like NICU hospitalization or perinatal complications (Mersky & Lee, 2019; Racine et al., 2018b; Zhang et al., 2017), the cumulative level of adversity may need to be at the extreme to influence the outcome, which suggests that the tipping point of an adverse outcome may be associated with some level of persistent, stress-related physiological damage (see Biological Embedding Model, Miller et al., 2011).

These findings are important as they confirm previous research while addressing some limitations present within other studies, such as the use of multiple

Table IV. *Logistic Regression Analysis of Maternal Perinatal Complication (Yes/No) by Exposure to Adverse Childhood Experiences (ACEs)*

Predictors	Maternal perinatal complication ($n = 123$)				
	B	SE	OR	95% CLs	
				Lower	Upper
Constant	−5.28**	1.39	0.00	—	—
Age (years)	0.06	0.04	1.06	0.98	1.14
Race = Black	0.54	0.54	1.72	0.59	4.98
Race = American Indian/Alaska Native	0.57	0.63	1.77	0.52	6.05
Race = Hispanic	0.71	0.77	2.03	0.45	9.20
Race = White, ref	—	—	—	—	—
BMI score[a]	0.07**	0.03	1.08	1.02	1.13
Self-reported smoking	−0.03	0.57	0.97	0.32	2.99
Self-reported alcohol use	0.28	0.62	1.33	0.39	4.52
Cotinine confirmed smoking[a]	0.27	0.57	1.32	0.43	3.99
0–2 ACEs, ref	—	—	—	—	—
3–5 ACEs	0.04	0.53	1.04	0.37	2.98
6+ ACEs	1.47**	.57	4.37	1.43	13.39

Note. OR = odds ratio. CL = confidence limit. All variables coded as yes/no (1/0) unless specified otherwise. Maternal perinatal complications included gestational diabetes, hypertension, other perinatal complication, perinatal loss (miscarriage, stillbirth), and emergency Cesarean section. Other perinatal complication included prenatal bleeding, postpartum hemorrhage, pain, blood clot, and infection. Smoking and alcohol use were self-reported across pregnancy. Cotinine levels were assayed from saliva.

[a]Assessed at first prenatal visit.

**$p < .01$.

reporters of pregnancy health behaviors and perinatal outcomes and prospective longitudinal data. There are several limitations to the current study findings, however. Self-reported ACEs, for example, may be under-reported due to social desirability or memory problems (Reuben et al., 2016). This may lead to conservative estimates of the association between maternal childhood adversity and perinatal health risks. Additionally, although we were able to confirm self-reported prenatal smoking behaviors at the first prenatal visit via cotinine levels present in saliva, we relied on self-reported alcohol use behaviors due to legal concerns for participants. Prenatal alcohol use also tends to be under-reported (Jacobson et al., 2002), but again, this is expected to conservatively bias findings.

Additionally, the sample size of our study limits our ability to examine individual maternal and infant perinatal complications individually. Although it is common to combine perinatal complications into single indicators of maternal and infant outcomes, the long-term implications and public health costs are not the same for all types of perinatal complications. A larger data set would enable this examination for specific outcomes of interest (e.g., gestational diabetes vs. hypertension), as well as provide the opportunity for more sensitive analyses according to racial identity. Finally, our sample may be unique in several ways that exacerbate health risks. Participants were recruited from predominately low-income serving perinatal clinics in a state that had not approved Medicaid expansion at the time of data collection. Approximately 52% of participants in the sample reported no health insurance at some point during the year leading up to pregnancy, which suggests that any underlying chronic conditions were likely to have been under-diagnosed and treated. The state where data collection occurred also ranks among the top five for ACEs according to a 2018 Child Trends report (Sacks & Murphey, 2018). Although we cannot, therefore, generalize about our findings, the high-risk nature of our sample presents an unusual opportunity to examine mechanisms linking maternal childhood adversity to perinatal outcomes because they are so prevalent among our study participants.

Finally, this study has important implications for perinatal and pediatric health care to address and mitigate the harmful effects of ACEs and prevent ongoing exposure to adversity. Routine screening for ACEs at OB-GYN, primary care, and pediatric clinics can help to identify women with a history of childhood adversity and provide an opportunity for additional prenatal support and monitoring, as well as appropriate referrals for mental health or substance use prevention or intervention services. Integrated care models with pediatric and perinatal health psychologists increase the availability and accessibility of prevention and intervention services, as well as provide a model for ongoing consultation and follow-up care for individuals and families who have experienced adversity (Brown et al., 2017; de Voursney & Huang, 2016; Woods-Jaeger et al., 2020).

The ICARE (Intergenerational and Cumulative Adverse and Resilient Experiences) model reviews

interventions that can support individuals and families exposed to adversity by promoting neurobiological and stress regulation, increasing adaptive behaviors, and reducing symptoms of stress or psychopathology (Hays-Grudo et al., 2020; Hays-Grudo et al., in press). For example, pregnant women who reveal a history of childhood adversity may benefit from mindfulness-based or cognitive-behavioral interventions designed to reduce stress, symptoms of anxiety and depression, substance use, and even the risk for adverse birth outcomes, as well as promote psychological well-being and positive health behaviors (e.g., Dhillon et al., 2017; Hicks et al., 2018; Vinci, 2020; Shreffler et al., 2019). Mothers and infants who have experienced an adverse perinatal complication or NICU hospitalization have been found to benefit from acute support and intervention prior to discharge with pediatric or health psychologists, as well as referrals for ongoing parenting and developmental support (Hynan et al., 2015; Spierling et al., 2019; Steinberg & Patterson, 2017), helping to reduce symptoms of stress or psychopathology, build adaptive skills, and reduce the risk for ongoing adversity.

Additionally, community-based models like Nurse–Family Partnership (Olds et al., 2014) and the By My Side Birth Support Program (Thomas et al., 2017) have shown success in reducing adverse birth outcomes among racial minority groups (see also Ellis et al., 2017; Porter et al. 2016). Moreover, the Battling Over Birth Report (Oparah et al., 2016) and Changing Woman Initiative (Gonzales, 2012) provide recommendations to reduce birth disparities among Black and American Indian/Alaska Native women, respectively, through culturally appropriate and equitable perinatal practices.

Policy implications may also be relevant; because childhood adversity is associated with chronic health conditions that increase the risk for adverse perinatal outcomes, health care programs designed to allow preconceptional women to receive physical and mental health treatment before they become pregnant may help to reduce potential impact of uncontrolled health conditions on perinatal outcomes. Therefore, to promote healthy infant outcomes, efforts should be made to identify mothers at risk for perinatal complications and increase psychosocial and medical support to ameliorate risks.

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References

American College of Obstetricians and Gynecologists, & Task Force on Hypertension in Pregnancy (2013). Hypertension in pregnancy. Report of the American College of Obstetricians and Gynecologists' Task Force on Hypertension in Pregnancy. *Obstetrics and Gynecology*, *122*(5), 1122–1131. https://doi.org/10.1097/01.AOG.0000437382.03963.88

Anachebe, N. F., & Sutton, M. Y. (2003). Racial disparities in reproductive health outcomes. *American Journal of Obstetrics and Gynecology*, *188*(4), S37–S42. 10.1067/mob.2003.245

Ancel, P.-Y., Goffinet, F., Kuhn, P., Langer, B., Matis, J., Hernandorena, X., Chabanier, P., Joly-Pedespan, L., Lecomte, B., Vendittelli, F., Dreyfus, M., Guillois, B., Burguet, A., Sagot, P., Sizun, J., Beuchée, A., Rouget, F., Favreau, A., Saliba, E., … Kaminski, M.; the EPIPAGE-2 Writing Group. (2015). Survival and morbidity of preterm children born at 22 through 34 weeks' gestation in France in 2011: Results of the EPIPAGE-2 Cohort Study. *JAMA Pediatrics*, *169*(3), 230–238. https://doi.org/10.1001/jamapediatrics.2014.3351

Anderson, J. E., Ebrahim, S., Floyd, L., & Atrash, H. (2006). Prevalence of risk factors for adverse pregnancy outcomes during pregnancy and the preconception period–United States, 2002-2004. *Maternal and Child Health Journal*, *10*(S1), S101–S106. https://doi.org/10.1007/s10995-006-0093-z

Baron, I. S., Litman, F. R., Ahronovich, M. D., & Baker, R. (2012). Late preterm birth: A review of medical and neuropsychological childhood outcomes. *Neuropsychology Review*, *22*(4), 438–450. https://doi.org/10.1007/s11065-012-9210-5

Beckie, T. M. (2012). A systematic review of allostatic load, health, and health disparities. *Biological Research for Nursing*, *14*(4), 311–346.

Bick, J., Naumova, O., Hunter, S., Barbot, B., Lee, M., Luthar, S. S., Raefski, A., & Grigorenko, E. L. (2012). Childhood adversity and DNA methylation of genes

involved in the hypothalamus-pituitary-adrenal axis and immune system: Whole-genome and candidate-gene associations. *Development and Psychopathology*, *24*(4), 1417–1425. https://doi.org/10.1017/S0954579412000806

Boyle, E. M., Poulsen, G., Field, D. J., Kurinczuk, J. J., Wolke, D., Alfirevic, Z., & Quigley, M. A. (2012). Effects of gestational age at birth on health outcomes at 3 and 5 years of age: Population based cohort study. *BMJ*, *344*(mar01 2), e896. https://doi.org/10.1136/bmj.e896

Braun, D., Braun, E., Chiu, V., Burgos, A. E., Gupta, M., Volodarskiy, M., & Getahun, D. (2020). Trends in neonatal intensive care unit utilization in a large integrated health care system. *JAMA Network Open*, *3*(6), e205239.https://doi.org/10.1001/jamanetworkopen.2020.5239

Braveman, P. (2014). What are health disparities and health equity? We need to be clear. *Public Health Reports*, *129*(1_suppl2), 5–8.

Brockie, T. N., Heinzelmann, M., & Gill, J. (2013). A famework to examine the role of epigenetics in health disparities among Native Americans. *Nursing Research and Practice*, *2013*:410395. https://doi.org/10.1155/2013/410395

Brown, D. W., Anda, R. F., Tiemeier, H., Felitti, V. J., Edwards, V. J., Croft, J. B., & Giles, W. H. (2009). Adverse childhood experiences and the risk of premature mortality. *American Journal of Preventive Medicine*, *37*(5), 389–396. 10.1016/j.amepre.2009.06.021

Brown, J. D., King, M. A., & Wissow, L. S. (2017). The central role of relationships with trauma-informed integrated care for children and youth. *Academic Pediatrics*, *17*(7S), S94–S101. https://doi.org/10.1016/j.acap.2017.01.013

Buss, C., Entringer, S., Moog, N. K., Toepfer, P., Fair, D. A., Simhan, H. N., Heim, C. M., & Wadhwa, P. D. (2017). Intergenerational transmission of maternal childhood maltreatment exposure: Implications for fetal brain development. *Journal of the American Academy of Child and Adolescent Psychiatry*, *56*(5), 373–382. https://doi.org/10.1016/j.jaac.2017.03.001

Centers for Disease Control. (CDC). (2017). *Pregnancy mortality surveillance system: Trends in pregnancy-related deaths*. Division of Reproductive Health, Centers for Disease Control. Retrieved from https://www.cdc.gov/reproductivehealth/maternalinfanthealth/pmss.html. (last accessed March 13, 2021)

Chae, D. H., Nuru-Jeter, A. M., Lincoln, K. D., & Francis, D. D. (2011). CONCEPTUALIZING RACIAL DISPARITIES IN HEALTH. *Du Bois Review: Social Science Research on Race*, *8*(1), 63–77. 10.1017/S1742058X11000166

Cheong, J. N., Wlodek, M. E., Moritz, K. M., & Cuffe, J. S. M. (2016). Programming of maternal and offspring disease: impact of growth restriction, fetal sex and transmission across generations. *The Journal of Physiology*, *594*(17), 4727–4740. 10.1113/JP271745 26970222

Christiaens, I., Hegadoren, K., & Olson, D. M. (2015). Adverse childhood experiences are associated with spontaneous preterm birth: A case-control study. *BMC Medicine*, *13*(1), 124.https://doi.org/10.1186/s12916-015-0353-0

Christian, L. M., Glaser, R., Porter, K., & Iams, J. D. (2013). Stress-Induced Inflammatory Responses in Women. *Psychosomatic Medicine*, *75*(7), 658–669. 10.1097/PSY.0b013e31829bbc89

Chung, E. K., Nurmohamed, L., Mathew, L., Elo, I. T., Coyne, J. C., & Culhane, J. F. (2010). Risky health behaviors among mothers-to-be: The impact of adverse childhood experiences. *Academic Pediatrics*, *10*(4), 245–251. https://doi.org/10.1016/j.acap.2010.04.003

Ciciolla, L., Armans, M., Addante, S., & Huffer, A. (2019). Racial disparities in pregnancy and birth outcomes. In H. E. Fitzgerald, D. J. Johnson, D. B. Qin, F. A. Villarruel, & J., Norder (Eds.), *Handbook on children and prejudice: Integrating research, practice, and policy*. Springer Press.

Collins, J. W., David, R. J., Handler, A., Wall, S., & Andes, S. (2004). Very low birthweight in African American infants: The role of maternal exposure to interpersonal racial discrimination. *American Journal of Public Health*, *94*(12), 2132–2138. https://doi.org/10.2105/AJPH.94.12.2132

de Voursney, D., & Huang, L. N. (2016). Meeting the mental health needs of children and youth through integrated care: A systems and policy perspective. *Psychological Services*, *13*(1), 77–91. https://doi.org/10.1037/ser0000045

Dhillon, A., Sparkes, E., & Duarte, R. V. (2017). Mindfulness-based interventions during pregnancy: A systematic review and meta-analysis. *Mindfulness*, *8*(6), 1421–1437. https://doi.org/10.1007/s12671-017-0726-x

Dong, M., Anda, R. F., Felitti, V. J., Dube, S. R., Williamson, D. F., Thompson, T. J., Loo, C. M., & Giles, W. H. (2004). The interrelatedness of multiple forms of childhood abuse, neglect, and household dysfunction. *Child Abuse & Neglect*, *28*(7), 771–784. 10.1016/j.chiabu.2004.01.008

Duffy, K. A., McLaughlin, K. A., & Green, P. A. (2018). Early life adversity and health-risk behaviors: Proposed psychological and neural mechanisms. *Annals of the New York Academy of Sciences*, *1428*(1), 151–169. https://doi.org/10.1111/nyas.13928

Ellis, W. R., & Dietz, W. H. (2017). A new framework for addressing adverse childhood and community experiences: The building community resilience model. *Academic Pediatrics*, *17*(7), S86-S93. 10.1016/j.acap.2016.12.011

Felitti, V. J., Anda, R. F., Nordenberg, D., Williamson, D. F., Spitz, A. M., Edwards, V., Koss, M. P., & Marks, J. S. (1998). Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults: The Adverse Childhood Experiences (ACE) Study. *American Journal of Preventive Medicine*, *14*(4), 245–258. https://doi.org/10.1016/S0749-3797(98)00017-8

Frankenberger, D. J., Clements-Nolle, K., & Yang, W. (2015). The association between adverse childhood experiences and alcohol use during pregnancy in a representative sample of adult women. *Women's Health Issues*, *25*(6), 688–695. https://doi.org/10.1016/j.whi.2015.06.007

Fryar, C. D., Carroll, M. D., & Ogden, C. L. (2012). *Prevalence of overweight, obesity, and extreme obesity among adults: United States, trends 1960–1962 through 2009–2010*. National Center for Health Statistics. Retrieved from https://www.cdc.gov/nchs/data/hestat/obesity_adult_13_14/obesity_adult_13_14.pdf. (last accessed March 13, 2021)

Gavin, A. R., Nurius, P., & Logan-Greene, P. (2012). Mediators of adverse birth outcomes among socially disadvantaged women. *Journal of Women's Health (2002)*, *21*(6), 634–642. https://doi.org/10.1089/jwh.2011.2766

Geronimus, A. T. (2001). Understanding and eliminating racial inequalities in women's health in the United States: the role of the weathering conceptual framework. *Journal of the American Medical Women's Association*, *56*(4), 133–136.

Geronimus, A. T., Hicken, M., Keene, D., & Bound, J. (2006). "Weathering" and age patterns of allostatic load scores among Blacks and whites in the United States. *American Journal of Public Health*, *96*(5), 826–833. https://doi.org/10.2105/AJPH.2004.060749

Geronimus, A. T., Hicken, M. T., Pearson, J. A., Seashols, S. J., Brown, K. L., & Cruz, T. D. (2010). Do US Black women experience stress-related accelerated biological aging? *Human Nature(Hawthorne, N.Y.)*, *21*(1), 19–38. https://doi.org/10.1007/s12110-010-9078-0

Gilbert, L. K., Breiding, M. J., Merrick, M. T., Thompson, W. W., Ford, D. C., Dhingra, S. S., & Parks, S. E. (2015). Childhood adversity and adult chronic disease. *American Journal of Preventive Medicine*, *48*(3), 345–349. https://doi.org/10.1016/j.amepre.2014.09.006

Giurgescu, C., Engeland, C. G., Zenk, S. N., & Kavanaugh, K. (2013). Stress, inflammation and preterm birth in African American women. *Newborn and Infant Nursing Reviews*, *13*(4), 171–177.

Gonzales, P. (2012). *Red medicine: Traditional Indigenous rites of birthing and healing*. University of Arizona Press.

Goodman, D. C., Ganduglia-Cazaban, C., Franzini, L., Stukel, T. A., Wasserman, J. R., Murphy, M. A., Kim, Y., Mowitz, M. E., Tyson, J. E., Doherty, J. R., & Little, G. A. (2019). Neonatal intensive care variation in Medicaid-insured newborns: A population-based study. *The Journal of Pediatrics*, *209*, 44–51.e2. https://doi.org/10.1016/j.jpeds.2019.02.014

Haidari, E. S., Lee, H. C., Illuzzi, J. L., Phibbs, C. S., Lin, H., & Xu, X. (2021). Hospital variation in admissions to neonatal intensive care units by diagnosis severity and category. *Journal of Perinatology*, *41*(3), 468–477. 10.1038/s41372-020-00775-z

Harrison, W., & Goodman, D. (2015). Epidemiologic trends in neonatal intensive care, 2007-2012. *JAMA Pediatrics*, *169*(9), 855–862. https://doi.org/10.1001/jamapediatrics.2015.1305

Harrison, W. N., Wasserman, J. R., & Goodman, D. C. (2018). Regional variation in neonatal intensive care admissions and the relationship to bed supply. *Journal of Pediatrics*, *192*, 73–79.e4. https://doi.org/10.1016/j.jpeds.2017.08.028.

Hays-Grudo, J., & Morris, A. S. (2020). *Adverse and Protective Childhood Experiences: A Developmental Perspective*. Washington, DC: American Psychological Association.

Hays-Grudo, J., Morris, A.S., Beasley, L., Ciciolla, L., Shreffler, K.M., & Croff, J. (In press). Integrating and synthesizing adversity and resilience knowledge and action: *The ICARE model. American Psychologist, Special Issue on Adverse Childhood Experiences*.

Hicks, L. M., Dayton, C. J., & Victor, B. G. (2018). Depressive and trauma symptoms in expectant, risk-exposed, mothers and fathers: Is mindfulness a buffer? *Journal of Affective Disorders*, *238*, 179–186. https://doi.org/10.1016/j.jad.2018.05.044

Hocher, B. (2014). More than genes: the advanced fetal programming hypothesis. *Journal of Reproductive Immunology*, *104-105*, 8–11. 10.1016/j.jri.2014.03.001

Hynan, M. T., Steinberg, Z., Baker, L., Cicco, R., Geller, P. A., Lassen, S., Milford, C., Mounts, K. O., Patterson, C., Saxton, S., Segre, L., & Stuebe, A. (2015). Recommendations for mental health professionals in the NICU. *Journal of Perinatology*, *35*(S1), S14–S18. https://doi.org/10.1038/jp.2015.144

Jacobson, S. W., Chiodo, L. M., Sokol, R. J., & Jacobson, J. L. (2002). Validity of maternal report of prenatal alcohol, cocaine, and smoking in relation to neurobehavioral outcome. *Pediatrics*, *109*(5), 815–825. https://doi.org/10.1542/peds.109.5.815

Keating, K., Murphey, D., Daily, S., Ryberg, R., & Laurore, J. (2020). *Maternal and child inequities emerge even before birth*. State of Babies Yearbook. Retrieved from https://stateofbabies.org/wp-content/uploads/2020/06/Maternal-and-Child-Health-Inequities-Emerge-Even-Before-Birth.pdf. (last accessed March 13, 2021)

Kim, S. (2016). Overview of cotinine cutoff values for smoking status classification. *International Journal of Environmental Research and Public Health*, *13*(12), 1236–1251. https://doi.org/10.3390/ijerph13121236

Lean, R. E., Rogers, C. E., Paul, R. A., & Gerstein, E. D. (2018). NICU Hospitalization: Long-term implications on parenting and child behaviors. *Current Treatment Options in Pediatrics*, *4*(1), 49–69. https://doi.org/10.1007/s40746-018-0112-5

Linehan, L. A., Walsh, J., Morris, A., Kenny, L., O'Donoghue, K., Dempsey, E., & Russell, N. (2016). Neonatal and maternal outcomes following midtrimester preterm premature rupture of the membranes: A retrospective cohort study. *BMC Pregnancy and Childbirth*, *16*, 25.https://doi.org/10.1186/s12884-016-0813-3

Lu, D., Palmer, J. R., Rosenberg, L., Shields, A. E., Orr, E. H., DeVivo, I., & Cozier, Y. C. (2019). Perceived racism in relation to telomere length among African American women in the Black Women's Health Study. *Annals of Epidemiology*, *36*, 33–39. https://doi.org/10.1016/j.annepidem.2019.06.003

Madigan, S., Wade, M., Plamondon, A., Maguire, J. L., & Jenkins, J. M. (2017). Maternal adverse childhood experience and infant health: Biomedical and psychosocial risks as intermediary mechanisms. *The Journal of Pediatrics*, *187*, 282–289.e1. https://doi.org/10.1016/j.jpeds.2017.04.052

Manuck, T. A., Rice, M. M., Bailit, J. L., Grobman, W. A., Reddy, U. M., Wapner, R. J., Thorp, J. M., Caritis, S. N., Prasad, M., Tita, A. T. N., Saade, G. R., Sorokin, Y., Rouse, D. J., Blackwell, S. C., Tolosa, J. E., Varner, M., Hill, K., Sowles, A., Postma, J., … VanDorsten, J. P.; Eunice Kennedy Shriver National Institute of Child Health and Human Development Maternal-Fetal Medicine Units Network. (2016). Preterm neonatal morbidity and mortality by gestational age: A contemporary cohort. *American*

Journal of Obstetrics and Gynecology, *215*(1), 103.e1–103.e14. https://doi.org/10.1016/j.ajog.2016.01.004

March of Dimes. (2011). Special care nursery admissions. Retrieved from https://www.marchofdimes.org/peristats/pdfdocs/nicu_summary_final.pdf. (last accessed March 13, 2021)

McEwen, B. S. (1998). Stress, adaptation, and disease: Allostasis and allostatic load. *Annals of the New York Academy of Sciences*, *840*(1), 33–44.

Mersky, J. P., & Lee, C. P. (2019). Adverse childhood experiences and poor birth outcomes in a diverse, low-income sample. *BMC Pregnancy and Childbirth*, *19*(1), 387.https://doi.org/10.1186/s12884-019-2560-8

Miller, G. E., Chen, E., & Parker, K. J. (2011). Psychological stress in childhood and susceptibility to the chronic diseases of aging: Moving toward a model of behavioral and biological mechanisms. *Psychological Bulletin*, *137*(6), 959–997. https://doi.org/10.1037/a0024768

Moen, A., Rønnestad, A., Stensvold, H. J., Uleberg, B., Olsen, F., & Byhring, H. S. (2017). The Norwegian neonatal healthcare atlas, 2009-2014: An analysis of admissions and treatments of infants at units for sick neonates in Norway in the period 2009-2014 (English version). Retrieved from https://helseatlas.no/sites/default/files/norwegian-neonatal-healthcare.pdf. (last accessed March 13, 2021)

Moster, D., Lie, R. T., & Markestad, T. (2008). Long-term medical and social consequences of preterm birth. *The New England Journal of Medicine*, *359*(3), 262–273. https://doi.org/10.1056/NEJMoa0706475

Muraskas, J., & Parsi, K. (2008). The cost of saving the tiniest lives: NICUs versus prevention. *The Virtual Mentor*, *10*(10), 655–658. https://doi.org/10.1001/virtualmentor.2008.10.10.pfor1-0810

Nicholson, L. M., Schwirian, P. M., & Groner, J. A. (2015). Recruitment and retention strategies in clinical studies with low-income and minority populations: Progress from 2004–2014. *Contemporary Clinical Trials*, *45*(Pt A), 34–40. https://doi.org/10.1016/j.cct.2015.07.008

Olds, D. L., Kitzman, H., Knudtson, M. D., Anson, E., Smith, J. A., & Cole, R. (2014). Effect of home visiting by nurses on maternal and child mortality: Results of a 2-decade follow-up of a randomized clinical trial. *JAMA Pediatrics*, *168*(9), 800-806. https://doi.org/10.1001/jamapediatrics.2014.472

Olson, D. M., Severson, E. M., Verstraeten, B. S., Ng, J. W., McCreary, J. K., & Metz, G. A. (2015). Allostatic load and preterm birth. *International Journal of Molecular Sciences*, *16*(12), 29856–29874. https://doi.org/10.3390/ijms161226209

Oparah, J.C., Arega, H., Hudson, D., Jones, L., & Oseguera, T. (2016). Battling over birth: Black women and the maternal health care crisis in California. Oakland, CA: *Black Women Birthing Justice*. Retrieved from http://www.blackwomenbirthingjustice.org/battling-over-birth

Pinheiro, T. V., Brunetto, S., Ramos, J. G. L., Bernardi, J. R., & Goldani, M. Z. (2016). Hypertensive disorders during pregnancy and health outcomes in the offspring: a systematic review. *Journal of Developmental Origins of Health and Disease*, *7*(4), 391–407. 10.1017/S2040174416000209

Porter, L., Martin, K., & Anda, R. (2016). Self-healing communities: A transformational process model for improving intergenerational health. *Robert Wood Johnson Foundation*. Retrieved from http://www.rwjf.org

Racine, N., Madigan, S., Plamondon, A., Hetherington, E., McDonald, S., & Tough, S. (2018a). Maternal adverse childhood experiences and antepartum risks: The moderating role of social support. *Archives of Women's Mental Health*, *21*(6), 663–670. https://doi.org/10.1007/s00737-018-0826-1

Racine, N., Plamondon, A., Madigan, S., McDonald, S., & Tough, S. (2018b). Maternal adverse childhood experiences and infant development. *Pediatrics*, *141*(4), e20172495.https://doi.org/10.1542/peds.2017-2495

Reuben, A., Moffitt, T. E., Caspi, A., Belsky, D. W., Harrington, H., Schroeder, F., Hogan, S., Ramrakha, S., Poulton, R., & Danese, A. (2016). Lest we forget: Comparing retrospective and prospective assessments of adverse childhood experiences in the prediction of adult health. *Journal of Child Psychology and Psychiatry*, *57*(10), 1103–1112. https://doi.org/10.1111/jcpp.12621

Robbins, C. L., Zapata, L. B., Farr, S. L., Kroelinger, C. D., Brian Morrow, B., Ahluwalia, I., D'Angelo, D. V., Barradas, D., Cox, S., Goodman, D., Williams, L., Grigorescu,V., Barfield, W. D.; Centers for Disease Control and Prevention (CDC). (2014). Centers for Disease Control and Prevention (CDC). Core state preconception health indicators - Pregnancy risk assessment monitoring system and behavioral risk factor surveillance system. *Morbidity and Mortality Weekly Report. Surveillance Summaries (Washington, DC: 2002)*, *63*(3), 1–62.

Roberts, A. L., Lyall, K., Rich-Edwards, J. W., Ascherio, A., & Weisskopf, M. G. (2013). Association of maternal exposure to childhood abuse with elevated risk for autism in offspring. *JAMA Psychiatry*, *70*(5), 508–515. https://doi.org/10.1001/jamapsychiatry.2013.447

Sanders, M. R., & Hall, S. L. (2018). Trauma-informed care in the newborn intensive care unit: Promoting safety, security and connectedness. *Journal of Perinatology*, *38*(1), 3–10. https://doi.org/10.1038/jp.2017.124

Sacks, V., & Murphey, D. (2018). *The prevalence of adverse childhood experiences, nationally, by state, and by race or ethnicity*. Child Trends. Retrieved from https://www.childtrends.org/publications/prevalence-adverse-childhood-experiences-nationally-state-race-ethnicity (last accessed March 13, 2021)

Schulman, J., Braun, D., Lee, H. C., Profit, J., Duenas, G., Bennett, M. V., Dimand, R. J., Jocson, M., & Gould, J. B. (2018). Association between neonatal intensive care unit admission rates and illness acuity. *JAMA Pediatrics*, *172*(1), 17–23. https://doi.org/10.1001/jamapediatrics.2017.3913

Sharma, D., Shastri, S., & Sharma, P. (2016). Intrauterine growth restriction: Antenatal and postnatal aspects. *Clinical Medicine Insights: Pediatrics*, *10*, 67–83.

Shreffler, K. M., Tiemeyer, S., Ciciolla, L., & Croff, J. M. (2019). Effect of a mindfulness-based pilot intervention on maternal-fetal bonding. *International Journal of Women's*

Health, *11*, 377–380. https://doi.org/10.2147/IJWH.S203836

Smith, M. V., Gotman, N., & Yonkers, K. A. (2016). Early childhood adversity and pregnancy outcomes. *Maternal and Child Health Journal*, *20*(4), 790–798. https://doi.org/10.1007/s10995-015-1909-5

Souza, R. T., Costa, M. L., Mayrink, J., Feitosa, F. E., Filho, E. A. R., Leite, D., Vettorazzi, J., Calderon, I. M., Sousa, M. H., Passini, R., Baker, P. N., Kenny, L., & Cecatti, J. G.; The Preterm SAMBA study group. (2020). Clinical and epidemiological factors associated with spontaneous preterm birth: A multicentre cohort of low risk nulliparous women. *Scientific Reports*, *10*(1), 855.https://doi.org/10.1038/s41598-020-57810-4

Spierling, T. N., Ciciolla, L., Tiemeyer, S., & Shreffler, K. M. (2019). Laying the groundwork for social and emotional development: Prenatal attachment, childbirth experiences, and neonatal attachment. In A. Morris, & A. Williamson (Eds.), *Building early social and emotional relationships in infants and toddlers: Integrating research and practice*. Springer Publishing.

Steinberg, Z., & Patterson, C. (2017). Giving voice to the psychological in the NICU: A relational model. *Journal of Infant, Child, and Adolescent Psychotherapy*, *16*(1), 25–44. https://doi.org/10.1080/15289168.2016.1267539

Stephens, B. E., Bann, C. M., Poole, W. K., & Vohr, B. R. (2008). Neurodevelopmental impairment: Predictors of its impact on the families of extremely low birth weight infants at 18 months. *Infant Mental Health Journal*, *29*(6), 570–587. https://doi.org/10.1002/imhj.20196

Thomas, M. P., Ammann, G., Brazier, E., Noyes, P., & Maybank, A. (2017). Doula services within a Healthy Start Program: Increasing access for an underserved population. *Maternal and Child Health Journal*, *21(Suppl 1)*, 59–64. https://doi.org/10.1007/s10995-017-2402-0

Vinci, C. (2020). Cognitive behavioral and mindfulness-based interventions for smoking cessation: A review of the recent literature. *Current Oncology Reports*, *22*(6), 58.https://doi.org/10.1007/s11912-020-00915w

Wallace, M. E., & Harville, E. W. (2013). Allostatic load and birth outcomes among White and Black women in New Orleans. *Maternal and Child Health Journal*, *17*(6), 1025–1029. https://doi.org/10.1007/s10995-012-1083-y

Woods-Jaeger, B., Thompson, J. E., Foye-Fletcher, A., Siedlik, E., Chakawa, A., Dalbey, K., & Gupta, R. C. (2020). Parent engagement in an integrated care parenting intervention to prevent toxic stress. *Clinical Practice in Pediatric Psychology*, *8*(3), 298–303. https://doi.org/10.1037/cpp0000361

Youssef, N. A., Belew, D., Hao, G., Wang, X., Treiber, F. A., Stefanek, M., Yassa, M., Boswell, E., McCall, W. V., & Su, S. (2017). Racial/ethnic differences in the association of childhood adversities with depression and the role of resilience. *Journal of Affective Disorders*, *208*, 577–581. https://doi.org/10.1016/j.jad.2016.10.024

Zhang, G., Feenstra, B., Bacelis, J., Liu, X., Muglia, L. M., Juodakis, J., Miller, D. E., Litterman, N., Jiang, P. P., Russell, L., Hinds, D. A., Hu, Y., Weirauch, M. T., Chen, X., Chavan, A. R., Wagner, G. P., Pavličev, M., Nnamani, M. C., Maziarz, J., Karjalainen, M. K., … Muglia, L. J. (2017). Genetic associations with gestational duration and spontaneous preterm birth. *The New England Journal of Medicine*, *377*(12), 1156–1167. https://doi.org/10.1056/NEJMoa1612665