Adverse Perinatal Outcomes Predicted by Prenatal Maternal Stress Among U.S. Women at the COVID-19 Pandemic Onset

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Abstract

Background High stress prenatally contributes to poor maternal and infant well-being. The coronavirus disease 2019 (COVID-19) pandemic has created substantial stress for pregnant women.

Purpose To understand whether stress experienced by women pregnant at the beginning of the pandemic was associated with a greater prevalence of adverse perinatal outcomes.

Methods Pregnant women across the USA aged ≥18 years old enrolled in a prospective cohort study during the pandemic onset (T1) in April–May 2020. This report focuses on the 1,367 participants who gave birth prior to July–August 2020 (T2). Hierarchical logistic regression models predicted preterm birth, small for gestational age infants, and unplanned operative delivery from T1 stress, sociodemographic, and medical factors.

Results After controlling for sociodemographic and medical factors, preterm birth was predicted by high prenatal maternal stress, delivering an infant small for gestational age was predicted by interpersonal violence and by stress related to being unprepared for birth due to the pandemic, and unplanned cesarean or operative vaginal delivery was predicted by prenatal appointment alterations, experiencing a major stressful life event, and

by stress related to being unprepared for birth due to the pandemic. Independent of these associations, African American women were more likely than other groups to deliver preterm.

Conclusion Pregnant women who are experiencing high stress during the COVID-19 pandemic are at risk of poorer perinatal outcomes. A longitudinal investigation is critical to determine whether prenatal maternal stress and resulting outcomes have longer-term consequences for the health and well-being of children born in the midst of the current pandemic.

Keywords: Pregnancy · Birth · Prenatal maternal stress · Adverse perinatal outcomes · COVID-19 pandemic · Pandemic-related stress · Behavioral medicine

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Introduction

The coronavirus disease 2019 (COVID-19) pandemic has changed the daily lives of people across the globe, causing tremendous psychological stress for parents and children [1, 2]. High levels of stress and anxiety were documented among women pregnant at the start of the pandemic [3–7]. Although the effects of SARS-CoV-2 infection on perinatal outcomes have not yet been definitively determined [8–12], there is a large body of existing literature demonstrating harmful effects of maternal psychological stress on adverse maternal and neonatal outcomes including preterm birth, low birth weight, small for gestational age, and unplanned operative delivery [13–16]. There is also evidence regarding the harmful effects of maternal psychological stress resulting from exposure to natural disasters on such outcomes [17–19]. Adverse perinatal outcomes subsequently predict a higher risk of neonatal mortality and morbidity as well as

chronic illnesses, temperamental difficulties, emotional dysregulation, and developmental delays in infancy and childhood [20, 21]. Therefore, it is critical to investigate whether maternal stress brought on by the COVID-19 pandemic is affecting infants born in its midst [22, 23].

Psychological stress is a multidimensional factor that can be defined and measured by three dimensions: stressful conditions or events, individual perceptions of stress, and emotions such as anxiety [24, 25]. All three of these stress dimensions were present at the onset of the COVID-19 pandemic and were evident in the experiences of pregnant women. Stressful conditions were produced by policies to reduce transmission by sheltering in place, social distancing caused disruptions to prenatal care and childbirth procedures [26–28], and high rates of pandemic-related economic strain [29, 30] and intimate partner violence were documented [31–33]. Pregnant women also reported experiencing high stress related to the potential impact of SARS-CoV-2 on the fetus and to their lack of preparation for the birth due to the pandemic [34]. Furthermore, significant elevations of depression and anxiety symptoms have been reported among pregnant women across the globe [3–7, 35]. The presence of these stressful conditions, perceptions, and emotions during this unprecedented and prolonged emergency raise the specter of serious population health consequences [36] for mothers and their offspring. Additionally, known social determinants of health may be putting particular groups of pregnant women at greater risk during the pandemic and exacerbating already stressful conditions. Reports indicate that pregnant African American women, and other women of color, who were under regular circumstances experience barriers to prenatal care and disproportionately high rates of adverse perinatal outcomes [37–39], have been particularly burdened by pandemic restrictions, and have higher rates of COVID-19 infection than other groups of pregnant women [40, 41].

To identify stress-related impacts of the COVID-19 pandemic on children born in its midst, there is a need to rigorously examine the potential contribution of prenatal maternal stress to adverse maternal and neonatal outcomes. The rigorous examination requires isolating the prospective prediction of adverse outcomes by all three prenatal stress dimensions, independent of other variables that are also associated with elevated risk for these outcomes, including medical factors and sociodemographic characteristics such as African American identity [42]. The current study presents such an investigation among women who gave birth in the midst of the pandemic.

Methods

Procedure and Participants

Data for this study are from the first and second timepoint of the COVID-19 Pregnancy Experiences (COPE) Study. Between April 24 and May 15, 2020, pregnant women across the USA at least 18 years of age were recruited to participate in the COPE Study through targeted Facebook advertisements (95% of participants) and invitations posted on pregnancy-related social media groups and pages (Facebook, Instagram, and Reddit). Advertisements and invitations included photos of pregnant women with varying racial and ethnic features and types of clothing to encourage wide participation. After reviewing study purposes and requirements and providing informed consent, participants completed an online questionnaire containing psychometrically rigorous instruments to assess stress, sociodemographic, and medical factors. In Summer 2020, 2,897 participants (65.5% retention rate) completed the second study questionnaire (T2; July 14 to August 21, 2020). The current analysis focuses on 1,367 COPE Study participants who reported a live birth at T2. Participants were entered into a raffle with a 1/100 chance to win a $100 gift card for each completed questionnaire. The study was approved by the Institutional Review Board of Stony Brook University.

Measures

Sociodemographic and medical factors. Well-demonstrated risk factors for the adverse perinatal outcomes examined in this study were assessed with relevant items [42]. *Sociodemographic characteristics* were assessed at T1 and included maternal age, race, and perceived financial status (below average/average/above average). *Obstetric characteristics* were assessed at T1 and included parity, gestational age, self-reported pregnancy risk (Yes/Unsure/No), and multiple gestations. *Health behaviors* included tobacco use and general healthy prenatal activities. Participants who endorsed tobacco use at either timepoint were considered tobacco users. General healthy prenatal behaviors were assessed at T1 by asking: "To what extent are you involved in healthy activities (eat well, take vitamins, exercise, sleep enough, etc.)" scored from 1 = *Very Little* to 5 = *Very Much*. *COVID-19 infection* was reported by participants at T1 and T2. Participants who endorsed positive results of antibody or viral testing at T1 or T2 were considered as having COVID-19 prenatally.

Stressful conditions. COVID-19 related income loss was assessed at T1 using the item: "Have you, or someone you rely on, lost income due to COVID-19?." *COVID-19 related prenatal appointment alteration* was assessed at T1 by asking: "Have you had prenatal care appointments canceled or rescheduled due to the current pandemic?." *Discrimination* was assessed at T2 using the item: "During your pregnancy, have you experienced discrimination or harassment because of your race, sexuality, gender, or body size?." *Interpersonal violence* was assessed at T2. Women were asked if they felt physically unsafe or emotionally unsafe in their home in the last 2 months. A participant who answered Yes to either situation was considered exposed to interpersonal violence. *Major life events during pregnancy* were assessed at T1 with the item: "Did any major negative or stressful life events (e.g., break-up, moving, death of someone close) happen in your life since you became pregnant?."

Stress perceptions. Pandemic-Related Pregnancy Stress was assessed at T1 using the Pandemic-Related Pregnancy Stress Scale (PREPS) [43]. It includes two internally consistent, pandemic-specific prenatal stress factors: Preparedness Stress (PREPS-Preparedness, seven items, $\alpha = 0.81$) and Perinatal Infection Stress (PREPS-Infection, five items, $\alpha = 0.86$). PREPS-Preparedness reflects concerns related to feeling unprepared for birth or postpartum due to the pandemic, with items such as: "I am worried that the pandemic could ruin my birth plans," "I am worried I will not be prepared for the birth due to the pandemic restrictions," and "I am concerned that I won't get the prenatal care I need because of COVID-19." PREPS-Infection reflects concerns about COVID-19 infection of oneself or one's infant/fetus, with items such as: "I am worried that my baby could get COVID-19 at the hospital after birth," "I am concerned that a COVID-19 infection could harm my pregnancy (such as miscarriage or preterm birth)," and "I am concerned about going to prenatal care appointments due to COVID-19." Scores for each PREPS scale are calculated as mean item response on a scale from 1 = *Very Little* to 5 = *Very Much*. *Prenatal Maternal Stress* was assessed at T1 using the Revised Prenatal Distress Questionnaire (NuPDQ) [44]. Respondents rate the extent to which they are "feeling bothered, upset, or worried" about 17 pregnancy-related stressors (e.g., "changes in your weight and body shape," "what will happen during labor and delivery," "whether you might have an unhealthy baby") on a scale from 0 = *Not at All* to 2 = *Very Much*. Scores were calculated as the mean response of items. The NuPDQ was internally consistent ($\alpha = 0.80$).

Stress emotions. General Anxiety Symptoms were assessed at T1 using the Generalized Anxiety Disorder-7 (GAD-7) [44], self-report measure of anxiety symptoms. Respondents report the frequency of symptoms over the last 2 weeks on a scale ranging from 0 = *Not at All* to 3 = *Nearly Every Day*. Scores were calculated as the sum of item responses with the following clinical cut-offs for anxiety severity: 0–4 minimal and 5–9 mild versus 10–14 moderate and 15–21 severe [44]. The instrument was internally consistent ($\alpha = 0.91$).

Adverse Perinatal Outcomes were reported at T2. *Preterm birth:* Participants who reported gestational age at delivery <37 weeks were classified as preterm. *Small for gestational age (SGA):* Based on participant-reported birth weight and gestational weeks at delivery, participants whose newborn weighed less than the 10th percentile for gestational age at delivery according to World Health Organization standards [45] were categorized as delivering an SGA infant. *Unplanned cesarean delivery or operative vaginal delivery (hereafter, unplanned operative delivery):* Participants who reported delivering via unplanned (including emergency) cesarean birth or assisted vaginal delivery were considered to have had an unplanned operative delivery.

Statistical Analysis

Statistical analyses were conducted using SPSS version 26.0. Univariate analyses were performed to examine associations among study variables. Thereafter, we conducted multivariate hierarchical binary logistic regression, separately predicting preterm birth, SGA, and unplanned operative delivery. Predictors in the first step of each regression analysis included sociodemographic variables, the second step added medical factors, and the third step added stress variables. This approach isolates the unique predictive value of stress variables beyond known sociodemographic and medical risk factors. Adjusted odds ratios and 95% confidence intervals were calculated for each predictor variable and p values < .05 were considered significant. Missing data for study variables was minimal, ranging from 0.0% to 0.1% per variable, and was missing completely at random (Little's Missing Completely at Random Test $p > .05$).

Results

Sample Characteristics and Perinatal Outcomes

The average age of the 1,367 study participants was 31.5 ± 4.4 years, average gestational age at T1 survey

completion was 34 weeks. 47.7% ($n = 651$) were nulliparas, and 1.7% ($n = 23$) had been diagnosed with SARS-CoV-2. On average, participants were 40 ± 21 days post-delivery at T2. Fewer than 3% identified themselves as African American. Additional sociodemographic and medical sample characteristics can be found in Table 1.

Study participants reported an array of stressful conditions, including 58.0% who had prenatal appointments canceled or altered due to the pandemic, 40.5% who experienced COVID-19 pandemic-related income loss, and 30.3% who experienced major life events during their pregnancy. Prevalence of stressful conditions, stress perceptions, and anxiety symptoms are presented in Table 2.

The rate of preterm delivery among study participants was 7.1% ($n = 97$) and 8.6% ($n = 115$) delivered an SGA infant. Close to a fifth (18.8%, $n = 252$) reported an unplanned operative delivery. Most of these were cesarean deliveries (15.1%, $n = 202$); the remainder were assisted vaginal deliveries (3.7%, $n = 50$).

Univariate Analyses

Participants who delivered preterm and those who had an unplanned operative delivery experienced greater Prenatal Maternal Stress and were more likely to report that they had experienced a major life event during pregnancy than participants who did not experience either of these adverse outcomes (Table 2). Unplanned operative delivery was also significantly more common among participants who reported alterations in their prenatal care and those who experienced greater Preparedness Stress. Participants who delivered an SGA infant were more likely to report interpersonal violence and experienced greater Preparedness Stress than those who did not deliver an SGA infant. Outcomes were also significantly related to SARS-CoV-2 diagnosis and to known sociodemographic and medical risk factors: that is, some outcomes were more common among participants who were African American, nulliparas, tobacco users, and those with high-risk pregnancy status (Table 1). Anxiety symptoms, Infection Stress, and other stress conditions (i.e., discrimination, income loss) were unrelated to adverse outcomes in the univariate analyses (Table 2).

Multivariate Analyses

Medical variables were significant and strong predictors of each of the adverse outcomes, yet stress variables that were entered in the third and final step of the regressions were independent predictors above and beyond both sociodemographic and medical variables. As displayed in Table 3, preterm birth was predicted by elevated Prenatal Maternal Stress. This type of stress increased the risk of preterm birth by 40% and overall, explained 1% of the variance in preterm birth, over and above maternal sociodemographic (i.e., African American racial identification) and medical characteristics (i.e., nulliparity, multiple gestation, and high-risk pregnancy) that also predicted preterm birth. As displayed in Table 4, stress explained 3% of the variance in SGA. Specifically, risk of SGA was approximately twice as great for women who experienced interpersonal violence, and 66% greater for those who reported higher Preparedness Stress. SGA was also more than five times greater for those who reported a SARS-CoV-2 diagnosis during pregnancy, and SGA was more prevalent among nulliparas, women with a high-risk pregnancy, and those who used tobacco. Finally, as seen in Table 5, stress explained 3% of the variance in an unplanned operative delivery. The odds of unplanned operative delivery increased by 51% and by for participants who reported alterations to prenatal appointments due to the pandemic and for those who experienced a major life event during pregnancy, respectively. Higher Preparedness Stress increased the odds of unplanned operative delivery by 32%, whereas moderate or severe anxiety symptoms decreased the odds of this outcome by 39%. These associations of stress variables with unplanned operative delivery were independent of the greater likelihood of unplanned operative delivery for nulliparas and those with high-risk pregnancy status. A summary of predictors for adverse perinatal outcomes can be seen in Fig. 1.

Discussion

Results of the present study demonstrate that the disruptive impact of the COVID-19 pandemic on prenatal care at the beginning of the pandemic, exposure to interpersonal violence, and other types of stress experienced by pregnant women during this period increased their risks of adverse perinatal outcomes. Findings from the hierarchical regressions indicate that beyond known medical and sociodemographic predictors, pandemic-related and general stressful conditions and perceptions of stress during pregnancy were associated with a greater likelihood of preterm birth, delivering an SGA infant, and unplanned operative delivery.

Of the stress dimensions examined in this study, prenatal maternal stress was the only stress variable that independently predicted preterm birth in the multivariate regression model. Prenatal maternal stress encompasses an array of pregnancy-specific concerns or worries that women may have about their physical changes and symptoms, the health of their fetus, impending labor and delivery, caring for a newborn, and changes in their interpersonal relationships [46]. The average level of

Table 1. Sociodemographic and Medical Characteristics and Univariate Associations with Adverse Perinatal Outcomes n(%)

	Total	Preterm birth			Small for gestational age			Unplanned operative delivery		
		No n = 1270 (92.9%)	Yes n = 97 (7.1%)	χ^2	No n = 1228 (91.4%)	Yes n = 115 (8.6%)	χ^2	No n = 1092 (81.2%)	Yes n = 252 (18.8%)	χ^2
Maternal age				0.36			0.82			0.76
<35 years	1034 (75.6)	963 (93.1)	71 (6.9)		932 (91.8)	83 (8.2)		820 (80.7)	196 (19.3)	
≥35 years	332 (24.3)	306 (92.2)	26 (7.8)		295 (90.2)	32 (9.8)		271 (82.9)	56 (17.1)	
African American				10.96**			5.21*			0.16
No	1328 (97.1)	1239 (93.3)	89 (6.7)		1198 (91.7)	108 (8.3)		1061 (81.2)	246 (18.8)	
Yes	39 (2.9)	31 (79.5)	8 (20.5)		30 (81.1)	7 (18.9)		31 (83.8)	6 (16.2)	
Financial Status				6.23*			3.72			3.68
Above or average	1193 (87.3)	1117 (93.6)	76 (6.4)		1077 (91.7)	98 (8.3)		948 (80.5)	229 (19.5)	
Lower	173 (12.7)	153 (88.4)	20 (11.6)		150 (89.8)	17 (10.2)		144 (86.7)	22 (13.3)	
Parity				8.44**			16.03***			124.34***
Nullipara	651 (47.7)	591 (90.8)	60 (9.2)		561 (88.2)	75 (11.8)		437 (68.7)	199 (31.3)	
Multipara	715 (52.3)	678 (94.8)	37 (5.2)		666 (94.3)	40 (5.7)		654 (92.5)	53 (7.5)	
Pregnancy risk				43.49***			5.09*			9.16**
Low risk	898 (65.7)	864 (96.2)	34 (3.8)		822 (92.7)	65 (7.3)		742 (83.6)	146 (16.4)	
High risk/unsure	469 (34.3)	406 (86.6)	63 (13.4)		406 (89.0)	50 (11.0)		350 (76.8)	106 (23.2)	
Multiple gestations				119.17***			0.68			0.36
No	1341 (98.1)	1260 (94.0)	81 (6.0)		1209 (91.5)	113 (8.5)		1076 (81.3)	247 (18.7)	
Yes	26 (1.9)	10 (38.5)	16 (61.5)		20 (90.5)	2 (9.5)		16 (76.2)	5 (23.8)	
Tobacco use				3.33			4.72*			0.08
No	1334 (97.6)	1242 (93.1)	92 (6.9)		1203 (91.7)	109 (8.3)		1067 (81.3)	246 (18.7)	
Yes	33 (2.4)	28 (84.8)	5 (15.2)		25 (80.6)	6 (19.4)		25 (80.6)	6 (19.4)	
COVID-19 Diagnosis				1.26			10.00***			0.38
No	1344 (98.3)	1250 (93.0)	94 (7.0)		1212 (91.7)	109 (8.3)		1073 (81.2)	249 (18.8)	
Yes	23 (1.7)	20 (87.0)	3 (13.0)		16 (72.7)	6 (27.3)		19 (86.4)	3 (13.6)	

*$p < .05$, **$p < .01$, ***$p < .001$.

Table 2. Stress at the Pandemic Onset and Univariate Associations with Adverse Perinatal Outcomes n(%)

	Total	Preterm birth			Small for Gestational Age			Unplanned operative delivery		
		No $n = 1270$ (92.9%)	Yes $n = 97$ (7.1%)		No $n = 1228$ (91.4%)	Yes $n = 115$ (8.6%)		No $n = 1092$ (81.2%)	Yes $n = 252$ (18.8%)	
Stress conditions				χ^2			χ^2			χ^2
COVID-19-related income loss				0.03			0.21			0.00
No	814 (59.6)	757 (93.0)	57 (7.0)		732 (91.7)	66 (8.3)		650 (81.3)	150 (18.8)	
Yes	553 (40.5)	513 (92.8)	40 (7.2)		496 (91.0)	49 (9.0)		442 (81.3)	102 (18.8)	
Prenatal care alterations				0.24			1.80			6.32*
No	574 (42.0)	531 (92.5)	43 (7.5)		508 (90.2)	55 (9.8)		476 (84.4)	88 (15.6)	
Yes	793 (58.0)	739 (93.2)	54 (6.8)		720 (92.3)	60 (7.7)		616 (79.0)	64 (21.0)	
Discrimination				0.07			0.00			0.14
No	1277 (93.4)	1187 (93.0)	90 (7.0)		1147 (91.5)	107 (8.5)		1021 (81.4)	34 (18.6)	
Yes	90 (6.6)	83 (92.2)	7 (7.8)		81 (91.0)	8 (9.0)		71 (79.8)	18 (20.2)	
Interpersonal violence				0.15			6.12*			2.09
No	1294 (94.7)	1203 (93.0)	7.0 (91)		1167 (91.9)	103 (8.1)		1028 (80.9)	43 (19.1)	
Yes	73 (5.3)	67 (91.8)	8.2 (6)		61 (83.6)	12 (16.4)		64 (87.7)	9 (12.3)	
Major life event				4.87*			0.02			4.45*
No	953 (69.7)	895 (93.9)	58 (6.1)		862 (91.5)	80 (8.5)		780 (82.7)	163 (17.3)	
Yes	414 (30.3)	375 (90.6)	9 (9.4)		366 (91.3)	35 (8.7)		312 (77.8)	89 (22.2)	
Stress perceptions $M \pm SD$				t			t			t
PREPS-Preparedness	3.43 ± 0.85	3.43 ± 0.85	3.50 ± 0.80	0.88	3.41 ± 0.85	3.65 ± 0.77	2.98*	3.39 ± 0.85	3.61 ± 0.82	3.42**
PREPS-Infection	3.21 ± 0.98	3.21 ± 0.97	3.20 ± 1.05	0.14	3.21 ± 0.97	3.25 ± 0.99	0.39	3.20 ± 0.97	3.26 ± 1.03	0.71
Prenatal Maternal Stress	0.82 ± 0.33	0.81 ± 0.33	0.91 ± 0.31	3.06**	0.81 ± 0.32	0.85 ± 0.33	1.28	0.80 ± 0.32	0.87 ± 0.32	2.90**
Stress emotions				χ^2			χ^2			χ^2
Anxiety Symptoms				0.22			0.13			1.06
None or Mild	891 (65.2)	826 (92.7)	65 (7.3)		802 (91.2)	77 (8.8)		708 (80.5)	172 (19.5)	
Moderate or severe	476 (34.8)	437 (93.3)	32 (6.7)		426 (91.8)	38 (8.2)		384 (82.8)	80 (17.2)	

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Notes:PREPS - Preparedness Pandemic-Related Prenatal Stress.

Table 3. Hierarchical Logistic Regression Predicting Preterm Birth from Sociodemographic, Medical, and Prenatal Stress Variables (n = 1,363)

	Step 1		Step 2		Step 3	
	AOR	95% CI	AOR	95% CI	AOR	95% CI
Below average income	**1.72***	**(1.01, 2.94)**	1.71	(0.93, 3.13)	1.65	(0.85, 3.19)
African American	**3.41****	**(1.51, 7.69)**	**2.92***	**(1.22, 6.95)**	**2.72***	**(1.10, 6.71)**
Older maternal age			0.90	(0.52, 1.53)	0.89	(0.52, 1.53)
Nulliparity			**2.07****	**(1.29, 3.32)**	**1.84***	**(1.13, 2.99)**
Multiple gestations			**15.05*****	**(6.24, 36.32)**	**14.52*****	**(5.90, 35.73)**
High-risk pregnancy			**3.42*****	**(2.10, 5.58)**	**3.41*****	**(2.07, 5.63)**
Healthy behaviors			1.13	(0.86, 1.47)	1.13	(0.86, 1.49)
Tobacco use			1.54	(0.50, 4.79)	1.33	(0.42, 4.26)
Diagnosed COVID-19			1.84	(0.45, 7.53)	1.81	(0.43, 7.55)
Discrimination					0.73	(0.29, 1.82)
Interpersonal violence					0.95	(0.35, 2.56)
Appointment alteration					0.93	(0.58, 1.47)
COVID-19 related income loss					0.91	(0.56, 1.48)
Major life event					1.42	(0.88, 2.29)
PREPS-Preparedness					0.98	(0.71, 1.35)
PREPS-Infection					0.90	(0.67, 1.20)
Prenatal Maternal Stress					**1.40***	**(1.03, 1.90)**
Moderate/ severe anxiety symptoms					0.68	(0.39, 1.20)
	$\Delta R^2 = 0.02$		$\Delta R^2 = 0.16$		$\Delta R^2 = 0.01$	
	$R^2 = 0.02$		$R^2 = 0.18$		$R^2 = 0.19$	

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Notes: *AOR* Adjusted Odds Ratio; *PREPS* Preparedness Pandemic-Related Prenatal Stress.

prenatal maternal stress in this study was higher than that reported across numerous prior studies using the same instrument [47]. We presume that this increase is attributable in part to the stressful circumstances that women likely experienced at the pandemic outbreak, including uncertainty about the impact of the virus on their and their infant's health, pandemic-related financial and employment strains, and the loss and closure of many childcare options, to name a few examples. As evidence of such associations, the correlation of the prenatal maternal stress variable (NuPDQ score) with each of the pandemic-related stress variables (PREPS-Preparation and PREPS-Infection) was $r = .55$, $p < .001$ and $r = .42$, $p = .42$, respectively, indicating that these types of stress did co-occur, although a portion of women's pregnancy-specific stress was unrelated to pandemic stressors. Prior studies have linked pregnancy-specific stress to preterm birth via unhealthful prenatal behaviors and inflammatory stress responses in pregnancy [16, 47–50] and there is evidence that this type of stress is a particularly strong predictor of preterm birth compared to other types of prenatal stress (see reviews by [47, 51]).

Despite the association of prenatal maternal stress with preterm birth, the overall rate of preterm birth in this sample (7.1%) was lower than the 2019 U.S. population average (10.2%) and lower than the White Non-Hispanic population average (9.3%), which may be a more fitting comparison given the composition of our study sample [52]. The lower prevalence of preterm birth could be attributable to the exclusion of minors from the study since youth is a risk factor for preterm birth, although some reports suggest that rates of preterm birth and SGA during the COVID-19 pandemic are lower than usual [53–55]. African American women in our study were more than twice as likely to deliver preterm than other study participants; their rate of preterm birth (20.5%) was higher than prepandemic U.S. population rates for African American women (14.4%) [52], although this should be interpreted with caution due to the small number of African American women in our sample ($n = 39$). Emerging evidence suggests that pregnant African American women and other women of color are being disproportionately affected during the COVID-19 pandemic [40], including evidence that SARS-CoV-2 [10] and pandemic-related restrictions

Table 4. Hierarchical Logistic Regression Predicting Small for Gestational Age Infant from Sociodemographic, Medical, and Prenatal Stress Variables (*n* = 1,339)

	Step 1		Step 2		Step 3	
	AOR	95% CI	AOR	95% CI	AOR	95% CI
Below average income	1.20	(0.70–2.08)	1.15	(0.64–2.04)	1.02	(0.55–1.91)
African American	**2.52***	**(1.08–5.89)**	2.25	(0.94–5.39)	2.14	(0.87–5.29)
Older maternal age			1.26	(0.78–2.01)	1.27	(0.79–2.06)
Nulliparity			**2.36***	**(1.55–3.59)**	**2.27***	**(1.47–3.50)**
Multiple gestations			0.84	(0.19–3.74)	0.77	(0.17–3.54)
High-risk pregnancy			**1.55***	**(1.01–2.38)**	**1.57***	**(1.01–2.44)**
Healthy behaviors			1.18	(0.93–1.49)	1.19	(0.93–1.52)
Tobacco use			**2.90***	**(1.10–7.66)**	**3.11***	**(1.14–8.49)**
Diagnosed COVID-19			**4.75****	**(1.76–12.82)**	**5.56****	**(2.04–15.18)**
Discrimination					0.85	(0.38–1.90)
Interpersonal violence					**2.31***	**(1.15–4.63)**
Appointment alteration					0.69	(0.46–1.03)
COVID-19 related income loss					0.95	(0.62–1.46)
Major life event					0.92	(0.59–1.44)
PREPS-Preparedness					**1.66****	**(1.23–2.23)**
PREPS-Infection					0.85	(0.66–1.09)
Prenatal Maternal Stress					0.92	(0.70–1.19)
Moderate/ severe anxiety symptoms					0.78	(0.48–1.26)
	$\Delta R^2 = 0.01$		$\Delta R^2 = 0.06$		$\Delta R^2 = 0.03$	
	$R^2 = 0.01$		$R^2 = 0.07$		$R^2 = 0.10$	

*p < 0.05, **p < 0.01, ***p < 0.001

Notes:*AOR* Adjusted Odds Ratio; *PREPS* - Preparedness Pandemic-Related Prenatal Stress.

on prenatal care have exacerbated longstanding racial inequities [41]. There is also growing recognition that pregnant Black women in the U.S. experience high levels of stress, including a potent type of stress that is unique to their intersecting gender, race, and pregnant status (sometimes labeled *gendered racism in pregnancy*), and that stress elevates African American women's risk of adverse outcomes—including preterm birth [37–39]. Comparison of the odds ratio from Step 1 to Step 3 (see Table 3) raises the possibility that the greater prevalence of preterm birth among African American women was attributable to some degree, although not entirely, to higher stress and to medical risk variables.

Two stress variables predicted a higher likelihood of delivering an SGA infant: higher stress about being unprepared for birth due to pandemic restrictions, and experiencing interpersonal violence, a known predictor of adverse perinatal outcomes [56, 57]. During the pandemic, women are at greater risk than ever when sheltering in place with a violent partner [31–33]. Being infected with SARS-CoV-2 during pregnancy was also a strong independent predictor of SGA, which may reflect medical consequences of the virus, as well as risk attributable to the stress that

women infected with SARS-CoV-2 during pregnancy are likely to experience.

Women who experienced a major life event during pregnancy, those who had prenatal appointments altered, and those who perceived greater stress because they felt unprepared for birth due to the pandemic were more likely to have an unplanned cesarean or operative vaginal delivery. A separate study of this cohort found that women with greater pandemic-related stress associated with feeling unprepared were more likely to prefer an in-hospital birth (vs. home birth or free-standing birth center) [58]. Ironically, hospital restrictions instituted during the pandemic to protect childbearing women may have increased the likelihood of operative deliveries. That is, women less informed about childbirth due to canceled prenatal appointments may have arrived at hospitals less prepared, more emotionally anxious, or in latent labor, which increases the likelihood of labor augmentation and unplanned cesarean delivery [59, 60]. Altered appointments may also represent missed opportunities to identify pregnancy complications that resulted in emergency deliveries [61]. These findings underscore the importance of ensuring that prenatal care is not disrupted, even when local SARS-CoV-2 infection rates are high.

Table 5. Hierarchical Logistic Regression Predicting Unplanned Operative Delivery from Sociodemographic, Medical, and Prenatal Stress Variables ($n = 1,328$)

	Step 1		Step 2		Step 3	
	AOR	95% CI	AOR	95% CI	AOR	95% CI
Below average income	0.73	(0.45–1.20)	0.71	(0.42–1.21)	0.70	(0.40–1.24)
African American	0.68	(0.24–1.93)	0.46	(0.15–1.36)	0.43	(0.14–1.33)
Older maternal age			0.91	(0.61–1.37)	0.88	(0.58–1.33)
Nulliparity			**6.31*****	**(4.34–9.17)**	**5.89*****	**(4.01–8.65)**
Multiple gestations			0.92	(0.28–3.00)	0.96	(0.29–3.17)
High-risk pregnancy			**1.93*****	**(1.37–2.72)**	**1.98*****	**(1.39–2.83)**
Healthy behaviors			**0.82***	**(0.68–0.98)**	**0.82***	**(0.68–1.00)**
Tobacco use			1.60	(0.59–4.29)	1.57	(0.58–4.22)
Diagnosed COVID-19			0.97	(0.27–3.54)	0.86	(0.23–3.19)
Discrimination					0.65	(0.33–1.30)
Interpersonal violence					0.82	(0.37–1.85)
Appointment alteration					**1.51***	**(1.08–2.12)**
COVID-19 related income loss					1.05	(0.75–1.48)
Major life event					**1.45***	**(1.03–2.05)**
PREPS-Preparedness					**1.32***	**(1.05–1.67)**
PREPS-Infection					0.93	(0.76–1.14)
Prenatal Maternal Stress					1.02	(0.82–1.27)
Moderate/ severe anxiety symptoms					**0.61***	**(0.41–0.91)**
	$\Delta R^2 = 0.00$		$\Delta R^2 = 0.16$		$\Delta R^2 = 0.03$	
	$R^2 = 0.00$		$R^2 = 0.16$		$R^2 = 0.19$	

*p < 0.05, **p < 0.01, ***p < 0.001

Notes:*AOR* Adjusted Odds Ratio; *PREPS* Preparedness Pandemic-Related Prenatal Stress.

Recent findings indicate that in-person prenatal care appointments do not expose pregnant women to greater infection risk [62].

Somewhat surprisingly, women with moderate or severe anxiety symptoms were less likely to have an unplanned operative delivery than women with minimal or mild anxiety symptoms. However, this finding may be attributable to an apparent association of anxiety with electing to have a scheduled cesarean delivery: 13.3% of women with minimal or mild anxiety symptoms had an elective cesarean delivery versus 19.4% of those who had moderate or severe anxiety symptoms.

The current study is the first in-depth examination of multiple dimensions of stress among women pregnant at the onset of the COVID-19 pandemic and it provides a unique, prospective investigation of their impact on perinatal outcomes. The study does, however, have several limitations related to its reliance on a self-selected cohort who were targeted via social media; the sample is also not racially and socioeconomically diverse and did not include minors. These recruitment and data collection methods were necessitated by pandemic-related constraints preventing face-to-face research recruitment and participation. Further large studies with more diverse samples are needed to validate study findings, as well as research employing more direct measurement of variables, such as through medical record data extraction (e.g., including medical factors such as obesity, substance use). Although there is evidence that women have a good recollection of birth events [63, 64] and pregnant women provide accurate information about their health status and behaviors (e.g., pregnancy risk, tobacco use) [65–67], the possibility of memory bias or distortion due to social desirability concerns cannot be ruled out in a study such as this.

Finally, results of the present study provide a strong foundation for further research investigating why particular outcomes are associated with some types of stress but not others. It is notable, for example, that preterm birth was predicted by nonpandemic, pregnancy-specific stress, that delivering an SGA infant was predicted by interpersonal violence and by pandemic-related pregnancy stress, and that unplanned operative delivery was predicted by a combination of pandemic-related and -unrelated, pregnancy-related and -unrelated stress factors. Although behavioral and biological pathways (including maternal neuroendocrine, immune, metabolic, and cardiovascular systems) have been shown to
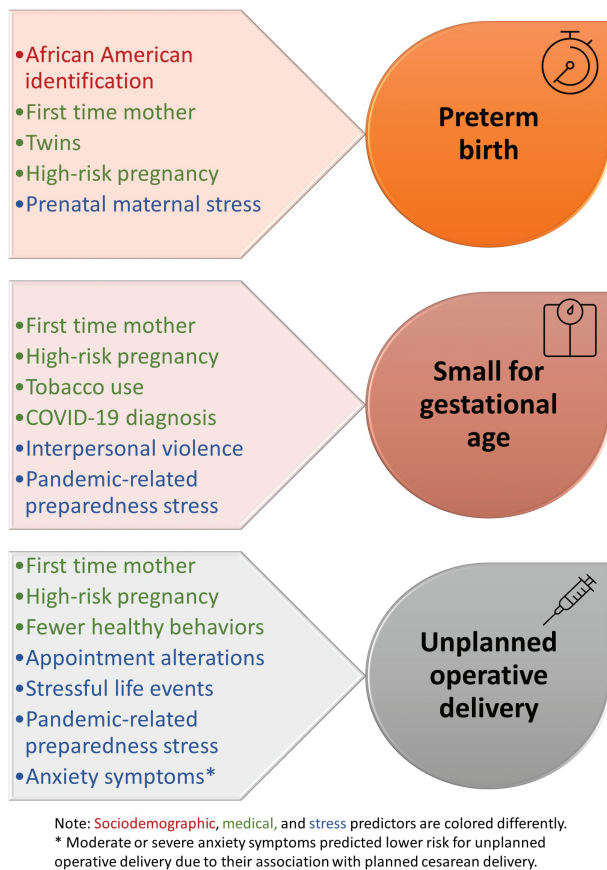
Note: Sociodemographic, medical, and stress predictors are colored differently.
* Moderate or severe anxiety symptoms predicted lower risk for unplanned operative delivery due to their association with planned cesarean delivery.

Figure 1. Predictors of perinatal outcomes during the COVID-19 pandemic ($N = 1,367$).

explain the association between prenatal stress and perinatal outcomes [15], existing evidence is not sufficiently advanced to link types of stress with the pathways that explain their impact on specific outcomes. This is an important avenue for future work.

Conclusions

Study findings offer evidence that particular groups of women, namely those experiencing stress surrounding specific aspects of being pregnant or who feel unprepared for birth, those who experience interpersonal violence, women who have experienced a major life event or disruptions to their prenatal care, those who were infected with COVID-19 during pregnancy, and women who identify as African American are at risk for adverse maternal and neonatal outcomes. Prenatal stress may have additional, undetected effects, as well. We do not know the potential impact on the future health and development of children born to mothers who experienced stress prenatally during the COVID-19 pandemic. Results of this study should be a clarion call for long-term, in-depth investigation and follow-up of these potentially vulnerable children.

Study findings demonstrate that appropriate care, attention, and resources that mitigate pregnant women's stress are likely to reduce their vulnerability to adverse outcomes. These findings have implications that will outlast the current pandemic and are relevant not merely in times of crisis, but for all pregnant women in all types of life circumstances. To promote population health, it is imperative to systematically identify, address, and resolve the stressful conditions experienced by women in the perinatal period, including those that further elevate the likelihood of adverse outcomes for African American women. Access to a safe living environment and the provision of high-quality medical care, including mental health and prenatal care, are critical for all pregnant women. Additionally, measures to identify [68] and help those experiencing high levels of stress—such as Screening, Brief Intervention and Referral to Treatment (SBIRT), psychoeducation, and other forms of mental health promotion such as the Collaborative Care model—may reduce women's risks [57, 69, 70]. During the COVID-19 pandemic, telehealth services for mental health treatment and prenatal care have expanded tremendously. Relevant technologies have been adapted to ensure high-quality, evidence-based, remote care [71, 72]. The acceptability of online care delivery platforms by clients, providers, and insurers has opened-up new possibilities for treatment and care in the perinatal period. For women seeking behavioral treatments, access to care has in the past often been impeded by stigma, financial strain, limited mobility, lack of childcare, and conflicts with work and other responsibilities [73, 74]. The possibility of receiving high-quality, evidence-based, effective individual or group care to reduce perinatal stress remotely [75] may be a silver lining of the COVID-19 pandemic, but only if existing racial and socioeconomic disparities in access to technology and facility with online platforms can be overcome [72, 76]. Findings of the current study demonstrate the urgency of such interventions to ensure the health and well-being of pregnant women and children born during the COVID-19 pandemic, but these exigencies will continue long beyond.

Compliance with Ethical Standards

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