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Perinatal Outcomes during versus Prior to the COVID-19 Pandemic and the Role of Maternal Depression and Perceived Stress: A Report from the ECHO Program

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Abstract

Objective—We sought to evaluate the impact of the coronavirus disease 2019 (COVID-19) pandemic on perinatal outcomes while accounting for maternal depression or perceived stress and to describe COVID-specific stressors, including changes in prenatal care, across specific time periods of the pandemic.

Study Design—Data of dyads from 41 cohorts from the National Institutes of Health Environmental influences on Child Health Outcomes Program ($N = 2{,}983$) were used to compare birth outcomes before and during the pandemic ($n = 2{,}355$), and a partially overlapping sample ($n = 1{,}490$) responded to a COVID-19 questionnaire. Psychosocial stress was defined using prenatal screening for depression and perceived stress. Propensity-score matching and general estimating equations with robust variance estimation were used to estimate the pandemic's effect on birth outcomes.

Results—Symptoms of depression and perceived stress during pregnancy were similar prior to and during the pandemic, with nearly 40% of participants reporting mild to severe stress, and 24% reporting mild depression to severe depression. Gestations were shorter during the pandemic ($B = -0.33$ weeks, $p = 0.025$), and depression was significantly associated with shortened gestation ($B = 0.02$ weeks, $p = 0.015$) after adjustment. Birth weights were similar ($B = 28.14$ g, $p = 0.568$), but infants born during the pandemic had slightly larger birth weights for gestational age at delivery than those born before the pandemic ($B = 0.15$ z-score units, $p = 0.041$). More women who gave birth early in the pandemic reported being moderately or extremely distressed about changes to their prenatal care and delivery (45%) compared with those who delivered later in the pandemic. A majority (72%) reported somewhat to extremely negative views of the impact of COVID-19 on their life.

Conclusion—In this national cohort, we detected no effect of COVID-19 on prenatal depression or perceived stress. However, experiencing the COVID-19 pandemic in pregnancy was associated with decreases in gestational age at birth, as well as distress about changes in prenatal care early in the pandemic.

Keywords

stress; pregnancy; COVID-19; perinatal; birth weight; gestational age

The association between psychosocial stress and adverse birth outcomes, such as preterm birth, has been well documented.[1,2] Evidence from clinical and epidemiologic studies, including natural experiments during times of disasters, demonstrates the adverse effects of both chronic and acute stress.[3] As demonstrated by the Dutch Hunger Winter study and other studies,[4,5] adverse exposures *in utero*, especially during critical periods of development, have lasting effects on offspring health outcomes.[6] Furthermore, adverse intrauterine exposures negatively impact birth outcomes, resulting in shortened gestation and low birth weight,[7] both of which are linked to a wide range of health outcomes across the lifespan, such as cardiovascular disease, type 2 diabetes, and certain cancers.[7–9]

During the coronavirus disease 2019 (COVID-19) pandemic, many individuals experienced increased stress caused by economic difficulties, social isolation due to stay-at-home orders, fear of illness, fear of infecting vulnerable family members or friends, and disruptions to prenatal care and delivery. The extent of these negative consequences varied according to individual situations and across time as cases surged[10] and as hospital systems experienced oscillating strain on their staff and infrastructure.[11] This stress of the pandemic may have directly impacted pregnancy health and birth outcomes. In addition, indirect stressors, such as disruptions to daily living and health care, experienced as a result of the pandemic and

the timing of pregnancy during different stages of the pandemic may have differential effects on birth outcomes. Further, the direct effects of increased stress during critical periods of fetal and infant development have long-lasting impacts for women and children.[11,12] Data from historical natural experiments and several frameworks have demonstrated the biological effects of in utero exposure to maternal psychosocial stress on adverse perinatal outcomes,[13–15] suggesting that the COVID-19 pandemic could have similar effects. Studies investigating the impact of the COVID-19 pandemic on maternal and child health have focused on the effects of SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2) infection during pregnancy on perinatal outcomes.[16–18] However, we hypothesized that the pandemic would also indirectly affect birth and neonatal outcomes due to the increased maternal psychosocial stress caused by pandemic conditions. While some studies have examined the pandemic's effect on birth outcomes,[19] few have included measures of maternal distress, the specific types of stressors that most affect pregnant women during the pandemic, or changes in women's experiences over the course of the COVID pandemic.

In the current study, we tested the effects of exposure to the COVID-19 pandemic on perinatal outcomes, without accounting for SARS-CoV-2 infection. We used data from cohorts in the National Institutes of Health (NIH) Environmental influences on Child Health Outcomes (ECHO) Program to describe maternal experiences of depressive symptoms and perceived stress prior to and during the pandemic, sources of maternal stress across pandemic time periods, and the association of these exposures with the following perinatal outcomes: gestational age at delivery, unadjusted birth weight, and birth weight adjusted for gestational age at delivery.

Materials and Methods

Overview

The ECHO Program is a diverse consortium of cohorts across the United States that has particular leverage for studying the impact of the pandemic on the health of the population. ECHO includes cohorts of caregivers and children enrolled from multiple existing longitudinal studies. It was designed to evaluate the impact of early-life exposures on child health outcomes and includes survey, medical record, and biospecimen collections; the design and purpose of the ECHO Program has been described.[20,21] ECHO cohorts have recruited pregnant women using a common protocol prepandemic and during the pandemic, and thus the ECHO Program allows for direct comparisons of birth outcomes prior to and during the first 15 months of the COVID-19 pandemic.

This analysis included a total of 2,983 participants who were pregnant before and/or during the COVID-19 pandemic and recruited from 41 ECHO cohorts across the United States, including Puerto Rico (►Fig. 1). Among these participants, 2,355 (drawn from 14 cohorts) had data available for the first analysis that compared birth outcomes prior to and during the COVID-19 pandemic. This first analysis will be referred to as "aim 1" throughout. In addition, 1,490 participants had data available for the second analysis that compared self-reported maternal stressors across four pandemic time periods. The second analysis drew from 37 cohorts and will be referred to as "aim 2" throughout. A total of 862 participants

were included in both the aim 1 and aim 2 samples. These 862 participants are accounted for in each of the within-aim totals above.

For aim 1, women who delivered between January 1, 2016, and March 11, 2020, were classified into the prepandemic group, and those who delivered after March 11, 2020, but before or on May 31, 2021, were classified into the pandemic group. For aim 2, birth outcomes, distress about prenatal care changes, and support from care providers were assessed in four pandemic time frames—February 28, 2020, to June 19, 2020; June 20, 2020, to September 27, 2020; September 28, 2020, to January 10, 2021; January 11, 2021, to May 31, 2021—based on surges in cases using U.S. data (https://ourworldindata.org/coronavirus/country/united-states).[10]

Data Collection

The primary outcomes of interest were birth weight, gestational age at delivery, and birth weight percentiles adjusted for gestational age at delivery. Birth weight percentile for gestational age using infant biological sex assigned at birth was derived based on 2017 U.S. reference data.[22] Gestational age at birth in weeks was categorized as preterm (<37 weeks), early term (37–38 weeks), full term (39–40 weeks), or late term (41 weeks).[23] Birth weight in grams was categorized as low birth weight (<2,500 g), normal birth weight (2,500–3,999 g), or macrosomic (4,000 g).[24,25] Birth weight and gestational age were primarily abstracted from the maternal or neonatal medical records, or if unavailable, were gathered from maternal self-report.

Maternal psychosocial stress was defined using: (1) maternal self-reports of depressive symptoms or (2) perceived stress within 8 months before the delivery date. Multiple scales for depression and perceived stress have been administered within ECHO cohorts and have been harmonized onto a common metric[26] using the scales of the Patient-Reported Outcomes Measurement Information System (PROMIS)[27,28] and NIH Toolbox[29] for maternal depression and perceived stress, respectively. A description of the specific scales that were administered by the cohorts in this analysis is provided in ►Supplementary Table S1 (available in the online version), e.g., the Edinburgh Postnatal Depression Scale (EPDS) was most commonly used to screen for maternal depression, and the Perceived Stress Scale (PSS) 10-item scale was the most common measure administered for perceived stress in the analytic sample (aim 1). Additionally, a set of cohorts administered a survey to determine sources of maternal stress specific to daily living and coping behaviors and overall maternal stress during the pandemic (aim 2). Due to the rapid deployment of the questionnaire in the midst of the pandemic, mothers completed the questionnaire either prospectively (62.4%) during their pregnancy or retrospectively (37.6%) after they gave birth but were asked about the prenatal period of exposure in both cases. As part of this survey, mothers were also asked to rate the impact of the COVID-19 pandemic on their lives using a 7-point scale: "Please indicate the extent to which you view the COVID-19 pandemic as having either a positive or negative impact on your life." In analyses, the 7-point scale was collapsed into a binary variable (negative impact, no/positive impact) and used to compare birth outcomes by maternal perception of acute stress. Descriptive statistics were summarized for the impact of the pandemic on the following factors: health care, in-person contact, childcare, behavior

change, stress sources, and coping behaviors during the pandemic. On this questionnaire, respondents also indicated if they (1) had tested positive for a SARS-CoV-2 infection or (2) had been told by a health care provider that they had, or likely had, COVID-19.

Relevant covariates and sociodemographic data were collected using methods approved for use in the ECHO Program. These methods include self-report, medical record abstraction, and interview-assisted survey completion.[30,31] Maternal race was categorized as white, black, Asian, Native Hawaiian or other Pacific Islander, American Indian or Alaska Native, Multiple races, and other race. Maternal ethnicity was categorized as Hispanic or non-Hispanic. Maternal age at the birth of their child was calculated as the child year of birth (from the Participant Registration Form) minus the maternal year of birth. Maternal education level included the following categories: less than high school; high school degree, General Education Development (GED), or equivalent; and some college, no degree, and higher. Income was classified as follows: <$30,000, 30,000–49,999, 50,000–74,999, 75,000–99,999, and 100,000 or more. Marital status included the categories of married or living with a partner or not married (widowed; separated; divorced; single, never married; partnered, not living together). Child biological sex assigned at birth was drawn from the Participant Registration Form, the Demographics of Child Form, or childbirth/neonatal medical record.

Statistical Analysis

Propensity score matching was applied to account for systematic differences in the demographic characteristics between the prepandemic and pandemic groups when estimating the effect of the pandemic on birth outcomes.[32] The two groups were propensity score–matched on maternal race, ethnicity, age, education, income, and marital status, as well as child sex. Only participants with complete data for these variables were included in the aim 1 analyses.

We applied generalized estimating equation (GEE) models with robust variance estimation to examine the pandemic effect on birth outcomes after accounting for maternal perceived stress and depression, respectively. We first identified six subsamples (►Table 1) from the matched sample, each with complete data for the exposure and outcome variables: (1) sample "a" with depression and birth weight ($n = 1,073$); (2) sample "b" with perceived stress and birth weight ($n = 655$); (3) sample "c" with depression and gestational age at delivery ($n = 1,468$); (4) sample "d" with perceived stress and gestational age at delivery ($n = 1,063$); (5) sample "e" with depression and birth weight adjusted for gestational age at delivery ($n = 1,073$); and (6) sample "f" with complete data in the perceived stress and birth weight adjusted for gestational age at delivery ($n = 655$). For each sub-sample, we conducted nested GEE models: a main effect analysis of the pandemic effect on the corresponding birth outcome and models regressing the pandemic effect on the birth outcome after accounting for either depression (a, c, e) or perceived stress (b, d, f). All analyses were conducted using R[33] and R packages of MatchIt[34] and geepack.[35]

Results

Participant Characteristics

This study included data from women enrolled in the ECHO Program who had a live birth between January 1, 2016 and May 31, 2021 and complete data on the matched covariates for propensity score matching. The aim 1 analysis included 2,355 women in the prepandemic ($n = 1,570$) and pandemic ($n = 785$) cohorts. The aim 2 analysis included a subsequent, partially overlapping subset of pregnant women with COVID-19 survey data ($N = 1,490$) who described stress in daily living and coping behaviors from March 11, 2020 to May 31, 2021. The demographic characteristics of both subsets of participants are shown in ►Table 2. Nearly two-thirds of participants were white, and about 80% were non-Hispanic. Most participants (approximately 80%) had some college education. Overall, 20 to 30% of participants had an annual income lower than $30,000, and about one-third had incomes higher than $100,000/year. Nearly 40% were either overweight or obese prior to pregnancy. The average maternal age was about 30 years. The mean gestational age at delivery was 38.5 weeks overall. Approximately 24% of pregnant women reported mild to severe depression, and approximately 45% reported mild to severe perceived stress. Using the propensity score–matched sample and continuous outcome data, birth weight, birth weight adjusted for gestational age at delivery, and gestational age at birth were similar before and during the pandemic.

Pregnant women who responded to the COVID-19 survey were similar to the pandemic and prepandemic cohorts (►Table 2). Approximately 10% of the sample responding to the COVID-19 survey (aim 2) self-reported having, or likely having, been infected with SARS-CoV-2.

Aim 1: Pandemic Experience, Psychosocial Stress, and Birth Outcomes

►Table 3 shows the results from models examining the effect of the COVID-19 pandemic on each birth outcome and maternal depression and perceived stress. Depression and perceived stress were highly correlated and thus modeled separately. On average, women who were pregnant during the pandemic had slightly earlier gestational ages at delivery compared with the prepandemic matched sample ($B = -0.33$ weeks, standard error [SE] = 0.149, $p = 0.025$). A null association was observed between pandemic experience and birth weight ($B = -28.14$ g, SE = 49.28, $p = 0.568$; R-squared = 0.001) and a small association was found between pandemic experience and adjusted birth weight ($B = 0.15$ z-score units, SE = 0.07, $p = 0.04$; R-squared < 0.001). Screening positive for depression was significantly associated with earlier gestational age at delivery ($B = -0.02$ weeks, $SE = 0.01$, $p = 0.015$) after accounting for the pandemic effect. However, only 1.3% of the variance in gestational age at delivery was explained by the pandemic and depression together.

Perceived stress among mothers was not significantly associated with birth weight ($B = -3.06$ g, SE = 2.72, $p = 0.260$), gestational age ($B = -0.01$ weeks, SE = 0; $p = 0.059$), or birth weight adjusted for gestational age at delivery ($B = 0$, SE = 0.01, $p = 0.423$) after accounting for the pandemic effect.

No evidence suggested that the pandemic was significantly associated with either depression or perceived stress (►Table 1). We performed a sensitivity analysis using data from two cohorts, which contributed around 30 and 40% of the total data in the pandemic sample, and a sensitivity analysis among women who reported having moderate to high depression or perceived stress levels during pregnancy. The results were quantitatively similar to those from the entire sample in that no significant pathways were found between the pandemic and either depression or perceived stress.

Aim 2: Specific Stressors, Coping Behaviors, and Disruptions to Prenatal Care during the Pandemic

Findings from the COVID-19–specific questionnaire highlight the many ways in which the lives of pregnant women were affected by the pandemic. In this sample ($n = 1,490$), 73.7% of pregnant women reported that the COVID-19 pandemic had a somewhat to extremely negative impact on their lives, whereas 13.6% reported no impact. The prevalence of stressors and coping behaviors in pregnant women during the COVID-19 pandemic is shown in ►Fig. 2. Specifically, with regard to the impact of the pandemic on health care (►Fig. 2A), 42% of perinatal women reported their health care provider changed to phone or online visits; 12% reported that they did not go to health care appointments due to concerns about entering their health care provider's office; and 16% reported their health care providers canceled appointments. In terms of social isolation (►Fig 2B), 67% reported that they had less in-person contact with family outside the home, and 73% reported less contact with friends during the pandemic.

Among participants who reported that they had a child in childcare (►Fig. 2C), 37% reported they and their spouse had to change their work schedule to care for their children, and 35% reported they had difficulties arranging for childcare. Some women (8%) reported they had to pay more for childcare since the pandemic began.

In terms of the pandemic impact on pregnant women's diet and exercise (►Fig. 2D), 60% reported that they ate more home-cooked meals. While 33% reported they performed less physical exercise, 17% reported exercising more compared with before the pandemic. Slightly more women reported they spent more time outdoors in nature (36%) compared with women who reported they spent less time in nature as a result of the pandemic (25%).

Participants reported that the greatest sources of psychosocial stress during the COVID-19 pandemic (►Fig. 2E) included health concerns (46%), the impact on their child and family members (46 and 47%, respectively), and social distancing or being quarantined (51%). Compared to these primary stress sources, participants were moderately stressed about financial concerns (34%) and were concerned about the pandemic's impact on work (30%) and their community (26%). A smaller number of participants were worried about access to food (13%), baby supplies (15%), personal care products or home supplies (18%), and medical care (14%).

Most participants reported positive adaptive behaviors to cope with the pandemic experience (►Fig. 2F). Specifically, they chose to talk with friends and family by phone, text, or video (69%); engage in more family activities (30%); and spend more time inside reading books

or doing puzzles and crosswords (25%) than prior to the pandemic. A small number of participants reported meditation and/or mindfulness practices (19%) and even fewer reported talking to health care or mental health providers more frequently (9%) as a result of the pandemic. Some participants (41%) spent more time on screens, such as TV, video games, and social media, and 25% ate more often, including snacking. Substance use in pregnancy was only reported by a small number of women as a coping behavior: alcohol in 5%, tobacco in 2%, and marijuana in 3%. Nearly 20% of respondents stated that they had not adopted any of the listed coping mechanisms.

Aim 2: Pandemic Experience, Prenatal Care, and Birth Outcomes

We further examined the prenatal care that women received across different pandemic time periods, and the association between distress related to their prenatal care during the pandemic and birth outcomes (►Table 4). Of the women who gave birth during the first wave of the pandemic (i.e., February 28, 2020–June 19, 2020), 45% were moderately or extremely distressed about changes to their prenatal care and birth experiences, and 25% reported that the support they received from their prenatal care provider(s) became somewhat or significantly worse. Women who gave birth during the earliest period of the pandemic were most likely to report feeling sometimes, rarely, or not at all happy and satisfied with life (35%). These rates declined as the pandemic continued to 28% of women who gave birth between September 28, 2020 and January 10, 2021 and to 15% of women who gave birth between January 11, 2021 and May 31, 2021. A similar trend in the prevalence of women reporting moderate to extreme dissatisfaction with their prenatal care was observed as the pandemic continued, starting with 43% and declining to 15% in the spring of 2021. No statistically significant differences were observed in gestational age at delivery, birth weight, or birth weight adjusted for gestational age at delivery across reporting periods (►Table 4).

Overall, when asked how they viewed COVID-19, 74% of pregnant women responded with somewhat, moderately, or extremely negative views. Pregnant women with negative feelings about the pandemic were more likely to be white, married or living with a partner, more highly educated with a higher income level, and older (►Supplementary Table S2, available in the online version). As shown in ►Table 5, birth weight adjusted for gestational age at delivery was higher for children born to mothers with overall positive or neutral feelings toward the pandemic compared with those born to women with negative feelings toward the pandemic ($p < 0.05$). However, birth weight and gestational age at delivery were similar for infants born to women regardless of the reported impact of COVID-19 on their lives. These results were similar when only those women who had completed the questionnaire while pregnant (i.e., prospectively) were included in the analysis (►Supplementary Table S3, available in the online version).

Discussion

Given the known association between psychosocial stress and adverse birth outcomes,[1,2] we sought to examine if the pandemic—widely regarded as a source of major stress—was associated with maternal stress and depression as well as birth weight and gestational age. In

addition, we aimed to describe COVID-19–specific stressors, including changes in prenatal care, experienced by pregnant individuals among dyads in a large national birth cohort program (ECHO) during specific time periods in the pandemic. This study is the first, to our knowledge, to include measures of maternal depression and perceived stress and assess their impact on birth outcomes prior to and during the COVID-19 pandemic across multiple U.S. cohorts and the first to provide a description of specific types and sources of stress reported by pregnant women across time during the first 15 months of the pandemic. Using a propensity score matching approach, we found that pandemic experience was associated with small effects on birth outcomes, including decreased gestational age at delivery and increased birth weight adjusted for gestational age at delivery. When using data from the COVID-19–specific questionnaire, we found that women who reported a positive impact or no impact of the pandemic on their lives had infants with slightly higher birth weight adjusted for gestational age at delivery.

Contrary to other studies that reported reductions in births prior to 37 weeks during the pandemic,[36–40] we did not detect a strong effect of the pandemic on birth outcomes. In fact, our results from the ECHO cohorts demonstrate small negative effects of the pandemic on gestational age at delivery (a decrease of 2.3 days) in the United States. However, such small effects may be meaningful at a population level and may have consequences across the life course.[41–43] Explanations for the difference may be that our study was large and composed of many sites throughout the United States. rather than a single site or clinical system. Additionally, pandemic impacts outside the United States may be distinct, and/or the data in this study were not limited to administrative data as prior studies have been.[36]

Levels of depression and perceived stress were similar prior to the pandemic and during the pandemic (aim 1). While reports from China[44] and Canada[45] indicate increased levels of depression and anxiety among pregnant individuals during the COVID-19 pandemic compared with before the pandemic, we did not observe similar trends in this large U.S. cohort. Several possible explanations may account for the essentially unchanged maternal depression and perceived stress during the study period. First, our results may reflect the experiences of segments of the population with resources or the resiliency to weather the impact of the pandemic. In addition, these results could highlight the fact that a large and increasing proportion of U.S. pregnant women—approximately 15% (which is slightly higher than the general population)[46,47]—experienced depressive symptoms and distress even prior to the pandemic.[48] Furthermore, the lack of an overall impact of the pandemic on stress and depression could suggest that some sub-populations of individuals may have experienced some benefits from other impacts of the pandemic.[49] For example, pandemic-induced changes in remote work could lead to reduced commuting, more positive coping and family time, or other changes.

We detected small negative effects of maternal depression, but not perceived stress, on birth outcomes during the pandemic. In this analysis, depression was associated with decreased gestational age at delivery and tended to be associated with decreased unadjusted birth weight. Depression has been linked to adverse birth outcomes, particularly gestational age at birth, in many previous studies.[15,50] It is possible that these effects operated through

other factors than the pandemic, and this observation suggests a need for future research to identify the potential mechanisms of pandemic-linked effects on birth outcomes.

The degree to which pregnant individuals perceived the impact of the pandemic on their lives varied widely, and temporal and geographic differences may have played a differential role in the impact of pandemic stressors across the study sites. COVID-19 stressors, such as childcare and finances, were only reported in a small number of pregnant individuals. Most, however, reported social isolation outside of their household and some impact on prenatal care, particularly early in the pandemic when there were many changes to policies, including restrictions on visitors or not allowing the partner to be present during labor and delivery, which are consistent with those in a small mixed-methods study.[51]

Limitations and Strengths

While our study had a generous sample size assembled from a large number of pregnancy and birth cohorts across the United States, it was not without limitations. First, the findings are limited to the cohorts that comprised the analytic sample, which may not be representative of the U.S. population although assembled from broad geographical locations (►Fig. 1B). The results are also bound to the timing of the assessments during a pandemic with oscillating rates of infection and dramatic changes in immunizations and therapeutics. Additionally, experiences and outcomes may vary by geography and sub-population as pandemic surges varied across place and time and were not equally or randomly distributed in the population. Second, complete data on the gestational age at COVID-19 survey completion were not available, which precluded us from accounting for the timing of psychosocial stress and specific stressors across the prenatal period. Third, women who were included in the analysis and had complete data available on depression and perceived stress may have been less impacted by the pandemic, both individually and geographically, or had more resources to mitigate its impact on their lives than those who did not respond.

Despite these weaknesses, our study is among the largest of its kind and included data from multiple sites across the United States. and across multiple time points during the first 15 months of the COVID-19 pandemic. It is unique for including the effect of maternal depression and perceived stress on birth outcomes using propensity score–matched samples in the period prior to and during the pandemic and for reporting specific stressors and a comprehensive assessment of the many ways the pandemic affected pregnant women. The results provide insight into the design of future research and modalities to best support mothers and their families during critical periods of human development.

Conclusion

In this national cohort, we detected no effect of the COVID-19 pandemic on prenatal depression or perceived stress. However, experiencing the COVID-19 pandemic in pregnancy was associated with decreases in gestational age at birth as well as distress about changes in prenatal care early in the pandemic.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Key Points

- COVID-19 was associated with shortened gestations.

- Depression was associated with shortened gestations.

- However, stress during the pandemic remained unchanged.

- Most women reported negative impacts of the pandemic.
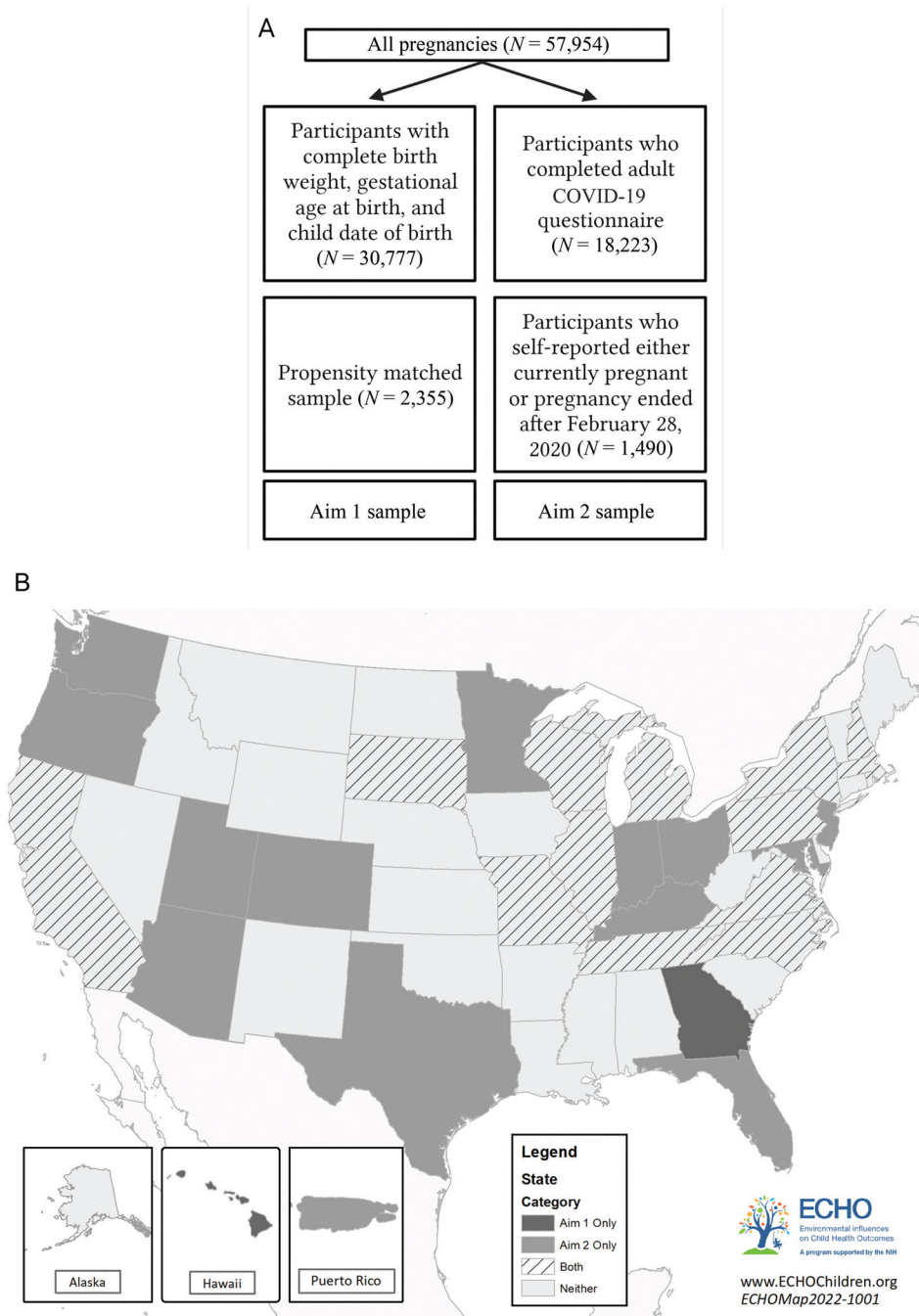
Fig. 1.
(A) Flow chart of study samples. **(B)** Map of the locations of ECHO sites that contributed data to aim 1, aim 2, or both. ECHO, Environmental influences on Child Health Outcomes.
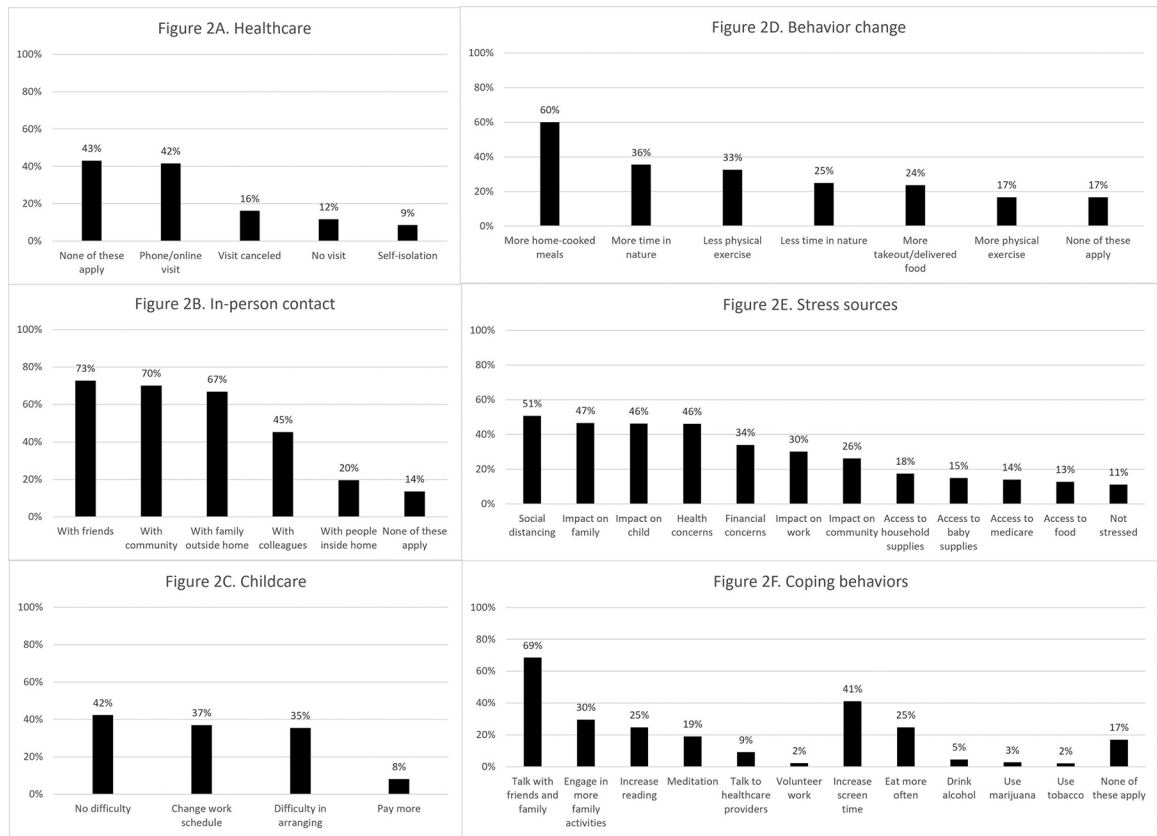
Fig. 2.
Stressors and coping behaviors during the COVID-19 pandemic. COVID-19, coronavirus disease 2019.

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Table 1

The six subsamples used in the general estimating equation (GEE) analyses

Subsample	Variables	Sample size
a	Depression, birth weight	1,073
b	Perceived stress, birth weight	655
c	Depression, gestational age at delivery	1,468
d	Perceived stress, gestational age at delivery	1,063
e	Depression, birth weight adjusted for gestational age at delivery	1,073
f	Perceived stress, birth weight adjusted for gestational age at delivery	655

Table 2

Participant characteristics of matched sample

Variable	Aim 1 sample				Aim 2 sample
	Prepandemic (N = 1,570)	Pandemic (N = 785)	Overall (N = 2,355)	p-Value	Overall (N = 1,490)
Race[a], N (%)				0.827	
White	1,169 (74.5%)	567 (72.2%)	1,736 (73.7%)		910 (72.4%)
Black	131 (8.34%)	67 (8.54%)	198 (8.41%)		166 (13.2%)
Asian	69 (4.39%)	33 (4.20%)	102 (4.33%)		33 (2.63%)
Native Hawaiian or other Pacific Islander	17 (1.08%)	10 (1.27%)	27 (1.15%)		<5 (0.5%)
American Indian or Alaska Native	45 (2.87%)	30 (3.82%)	75 (3.18%)		59 (4.69%)
Multiple race	47 (2.99%)	28 (3.57%)	75 (3.18%)		66 (5.25%)
Other race	92 (5.86%)	50 (6.37%)	142 (6.03%)		<30 (<2.5%)
Missing					233 (15.6%)
Ethnicity[a], N (%)				0.741	
Non-Hispanic	1,308 (83.3%)	649 (82.7%)	1,957 (83.1%)		1,074 (78.1%)
Hispanic	262 (16.7%)	136 (17.3%)	398 (16.9%)		301 (21.9%)
Missing					115 (7.7%)
Education[a], N (%)				0.424	
Less than high school	61 (3.89%)	32 (4.08%)	93 (3.95%)		79 (7.05%)
High school degree, GED, or equivalent	174 (11.1%)	101 (12.9%)	275 (11.7%)		166 (14.8%)
Some college or higher	1,335 (85.0%)	652 (83.1%)	1,987 (84.4%)		875 (78.1%)
Missing					370 (24.8%)
Income[a], N (%)				0.902	
<$30,000	326 (20.8%)	177 (22.5%)	503 (21.4%)		301 (29.6%)
$30,000–49,999	172 (11.0%)	84 (10.7%)	256 (10.9%)		115 (11.3%)
$50,000–74,999	177 (11.3%)	89 (11.3%)	266 (11.3%)		142 (14.0%)
$75,000–99,999	246 (15.7%)	120 (15.3%)	366 (15.5%)		169 (16.6%)
$100,000 or more	649 (41.3%)	315 (40.1%)	964 (40.9%)		289 (28.4%)
Missing					474 (31.8%)
Marital status[a], N (%)				0.403	
Married or living with a partner	1,392 (88.7%)	686 (87.4%)	2,078 (88.2%)		959 (82.7%)

	Aim 1 sample				Aim 2 sample
Variable	Prepandemic (*N* = 1,570)	Pandemic (*N* = 785)	Overall (*N* = 2,355)	*p*-Value	Overall (*N* = 1,490)
Not married (widowed; separated; divorced; single, never married; partnered [boyfriend or girlfriend], not living together)	178 (11.3%)	99.0 (12.6%)	277 (11.8%)		201 (17.3%)
Missing					330 (22.1%)
Child sex[a], *N* (%)					
Female	813 (51.8%)	392 (49.9%)	1,205 (51.2%)	0.423	625 (51.8%)
Male	757 (48.2%)	393 (50.1%)	1,150 (48.8%)		581 (48.2%)
Missing					284 (19.1%)
Parity, *N* (%)					
0	283 (46.9%)	39 (17.3%)	322 (38.8%)	<0.001	121 (25.1%)
1	192 (31.8%)	120 (53.3%)	312 (37.6%)		222 (46.0%)
2	87 (14.4%)	34 (15.1%)	121 (14.6%)		81 (16.8%)
3	42 (6.95%)	32 (14.2%)	74 (8.92%)		59 (12.2%)
Missing	966 (61.5%)	560 (71.3%)	1,526 (64.8%)		1,007 (67.6%)
Birth weight category, *N* (%)					
Low birth weight (<2,500 g)	104 (7.77%)	32.0 (7.26%)	136 (7.64%)	0.574	42 (5.56%)
Normal birth weight (2,500 g and <4,000 g)	1,124 (84.0%)	379 (85.9%)	1,503 (84.5%)		649 (86.0%)
Macrosomia (4,000 g)	110 (8.22%)	30 (6.80%)	140 (7.87%)		64 (8.48%)
Missing	232 (14.8%)	344 (43.8%)	576 (24.5%)		735 (49.3%)
Gestational age category, *N* (%)					
Preterm (36 weeks)	166 (10.6%)	80.0 (10.3%)	246 (10.5%)	0.204	100 (8.31%)
Early term (37–38 weeks)	408 (26.1%)	221 (28.3%)	629 (26.8%)		326 (27.1%)
Full term (39–40 weeks)	860 (54.9%)	431 (55.3%)	1,291 (55.0%)		682 (56.7%)
Late term (41 weeks)	<150 (<10%)	<50 (<4.0%)	180 (7.67%)		95 (7.90%)
Missing	<5 (<0.3%)	<10 (0.6%)	9.00 (0.4%)		287 (19.3%)
Prepregnancy BMI category, *N* (%)					
Underweight	23 (1.72%)	12 (2.25%)	35 (1.87%)	0.0642	13 (1.54%)
Normal weight	660 (49.3%)	238 (44.6%)	898 (47.9%)		345 (40.9%)
Overweight	349 (26.0%)	132 (24.7%)	481 (25.7%)		204 (24.2%)
Obese	308 (23.0%)	152 (28.5%)	460 (24.5%)		282 (33.4%)
Missing	230 (14.6%)	251 (32.0%)	481 (20.4%)		646 (43.4%)

| Variable | Aim 1 sample | | | | Aim 2 sample |
	Prepandemic (N = 1,570)	Pandemic (N = 785)	Overall (N = 2,355)	p-Value	Overall (N = 1,490)
Maternal age[a]					
Mean (SD)	31.4 (5.25)	31.3 (5.03)	31.4 (5.17)	0.668	29.7 (5.17)
Median [min, max]	32.0 [17.0, 49.0]	31.0 [19.0, 44.0]	32.0 [17.0, 49.0]		30.0 [17.0, 43.0]
Missing	235 (15.0%)	346 (44.1%)	581 (24.7%)		262 (17.6%)
Adjusted birth weight					
Mean (SD)	0.0631 (1.08)	0.0941 (0.988)	0.0708 (1.06)	0.578	0.130 (1.04)
Median [min, max]	0.0176 [−3.99, 4.99]	0.127 [−3.21,3.35]	0.0530 [−3.99, 4.99]		0.138 [−3.21,4.32]
Missing	235 (15.0%)	344 (43.8%)	581 (24.7%)		735 (49.3%)
Birth weight					
Mean (SD)	3,290 (601)	3,290 (578)	3,290 (595)	0.992	3,350 (550)
Median [min, max]	3,350 [665, 5,440]	3,360 [539, 4,590]	3,350 [539, 5,440]		3,400 [490, 5,370]
Missing	232 (14.8%)	344 (43.8%)	576 (24.5%)		735 (49.3%)
Gestational age at birth					
Mean (SD)	38.5 (2.14)	38.5 (1.94)	38.5 (2.08)	0.611	38.6 (1.90)
Median [min, max]	39.0 [24.0, 42.0]	39.0 [23.0, 43.0]	39.0 [23.0, 43.0]		39.0 [23.0, 42.0]
Missing	<5 (<0.3%)	<10 (0.6%)	9.00 (0.4%)		287 (19.3%)
Depression category					
Normal	639 (75.4%)	486 (78.0%)	1,125 (76.5%)	0.672	519 (78.6%)
Mild	130 (15.3%)	83 (13.3%)	213 (14.5%)		84.0 (12.7%)
Moderate	72 (8.50%)	49 (7.87%)	121 (8.23%)		<60 (9.0%)
Severe	6 (0.708%)	5 (0.803%)	11 (0.748%)		<5 (<0.7%)
Missing	723 (46.1%)	162 (20.6%)	885 (37.6%)		830 (55.7%)
PSS category					
Low	322 (56.2%)	290 (59.1%)	612 (57.5%)	0.8	423 (60.9%)
Mild	178 (31.1%)	140 (28.5%)	318 (29.9%)		199 (28.6%)
Moderate	56 (9.77%)	46 (9.37%)	102 (9.59%)		58 (8.35%)
Severe	17 (2.97%)	15 (3.05%)	32 (3.01%)		15 (2.16%)
Missing	997 (63.5%)	294 (37.5%)	1,291 (54.8%)		795 (53.4%)
COVID-19-positive (including likely)					
No					1,342 (90.1%)

Variable	Aim 1 sample				Aim 2 sample
	Prepandemic (N = 1,570)	Pandemic (N = 785)	Overall (N = 2,355)	p-Value	Overall (N = 1,490)
Yes					<150 (10%)
Missing					<5 (0.3%)

Abbreviations: BMI, body mass index; COVID-19, coronavirus disease 2019; GED, General Educational Development; PSS, Perceived Stress Scale; SD, standard deviation.

Note: p-Values for chi-squared tests were computed across categories excluding the missing category for all categorical variables between the prepandemic and pandemic groups. COVID-19-positive tests were only collected in the aim two sample.

[a] Covariates used in propensity score matching for aim 1. Complete data of these variables were used.

Table 3

I impact of COVID-19 pandemic on birth outcomes

Models	Predictor	Estimate	SE	Wald	p
I	Predictors of birth weight				
N = 1,073	Intercept	3,254.12	30.65	11,274.37	0.00
	Pandemic group	31.78	24.08	1.74	0.19
	R-squared statistic	0.00			
II	Predictors of birth weight				
N = 1,073	Intercept	3,549.28	177.16	401.37	0.00
	Pandemic group	34.43	19.40	3.15	0.08
	Depression during pregnancy	−6.06	3.26	3.45	0.06
	R-squared statistic	0.008			
III	Predictors of birth weight				
N = 655	Intercept	3,356.70	47.50	4,993.23	0.00
	Pandemic group	−28.14	49.28	0.33	0.57
	R-squared statistic	0.001			
IV	Predictors of birth weight				
N = 655	Intercept	3,504.64	172.97	410.55	0.00
	Pandemic group	−29.19	47.69	0.37	0.54
	Perceived stress during pregnancy	−3.06	2.72	1.27	0.26
	R-squared statistic	0.004			
V	Predictors of gestational age at birth				
N = 1,468	Intercept	38.61	0.11	116,826.47	0.00
	Pandemic group	−0.21	0.16	1.76	0.18
	R-squared statistic	0.00			
VI	Predictors of gestational age at birth				
N = 1,468	Intercept	39.81	0.50	6,297.30	0.000
	Pandemic group	−0.22	0.17	1.65	0.199
	Depression during pregnancy	−0.02	0.01	5.91	0.015
	R-squared statistic	0.013			
VII	Predictors of gestational age at birth				
N = 1,063	Intercept	38.78	0.14	75,212.94	0.00

Models	Predictor	Estimate	SE	Wald	p
	Pandemic group	−0.33	0.15	5.01	0.03
	R-squared statistic	0.008			
VIII	Predictors of gestational age at birth				
N = 1,063	Intercept	39.14	0.24	27,041.33	0.00
	Pandemic group	−0.33	0.15	5.19	0.02
	Perceived stress during pregnancy	−0.01	0.00	3.58	0.06
	R-squared statistic	0.010			
IX	Predictors of adjusted birth weight				
N = 1,073	Intercept	−0.05	0.08	0.42	0.516
	Pandemic group	0.15	0.07	4.16	0.041
	R-squared statistic	0.00			
X	Predictors of adjusted birth weight				
N = 1,073	Intercept	0.05	0.17	0.08	0.781
	Pandemic group	0.15	0.07	4.49	0.034
	Depression during pregnancy	0.00	0.00	0.40	0.527
	R-squared statistic	0.005			
XI	Predictors of adjusted birth weight				
N = 655	Intercept	0.09	0.11	0.74	0.39
	Pandemic group	0.10	0.11	0.87	0.35
	R-squared statistic	0.002			
XII	Predictors of adjusted birth weight				
N = 655	Intercept	0.30	0.36	0.71	0.399
	Pandemic group	0.10	0.11	0.86	0.353
	Perceived stress during pregnancy	0.00	0.01	0.64	0.423
	R-squared statistic	0.004			

Abbreviation: COVID-19, coronavirus disease 2019; SE, standard error.

Table 4

Impact of pandemic period on birth outcomes and prenatal care

Delivery dates by four pandemic periods	February 28, 2020-June 19, 2020	June 20, 2020-September 27, 2020	September 28, 2020-January 10, 2021	January 11, 2021-May 31, 2021	Missing	Overall	p-Value
	(N=224)	(N=183)	(N=183)	(N=201)	(N=699)	(N=1,490)	
Adjusted birth weight							
Mean (SD)	0.159 (1.07)	0.270 (0.965)	0.129 (0.842)	0.255 (0.881)	0.0644 (1.12)	0.130 (1.04)	0.93
Median [min, max]	0.256 [−3.21, 2.49]	0.270 [−1.57, 2.20]	0.0604 [−1.84, 2.13]	0.257 [−1.59, 2.54]	0.0530 [−2.89, 4.32]	0.138 [−3.21, 4.32]	
Missing	77 (34.4%)	96 (52.5%)	81 (44.3%)	141 (70.1%)	340 (48.6%)	735 (49.3%)	
Birth weight							
Mean (SD)	3,380 (488)	3,370 (577)	3,280 (552)	3,430 (451)	3,350 (582)	3,350 (550)	0.30
Median [min, max]	3,410 [1,520, 4,480]	3,430 [1,470, 4,340]	3,350 [539, 4,420]	3,430 [2,100, 4,590]	3,380 [490, 5,370]	3,400 [490, 5,370]	
Missing	77 (34.4%)	96 (52.5%)	81 (44.3%)	141 (70.1%)	340 (48.6%)	735 (49.3%)	
Gestational age at birth							
Mean (SD)	38.6 (1.59)	38.5 (1.94)	38.5 (1.99)	38.5 (1.70)	38.7 (2.07)	38.6 (1.90)	0.70
Median [min, max]	39.0 [32.0, 41.0]	39.0 [29.0, 41.0]	39.0 [23.0, 42.0]	39.0 [29.0, 42.0]	39.0 [24.0, 42.0]	39.0 [23.0, 42.0]	
Missing	<5 (<3%)	10 (5.5%)	<5(<3%)	<5 (<3%)	269 (38.5%)	287 (19.3%)	
Birth weight category, N (%)							
Low birth weight (<2,500 g)	8 (5.44%)	5 (5.75%)	5 (4.90%)	2 (3.33%)	22 (6.13%)	42 (5.56%)	0.26
Normal birth weight (2,500 g and <4,000 g)	130 (88.4%)	70 (80.5%)	92 (90.2%)	55 (91.7%)	302 (84.1%)	649 (86.0%)	
Macrosomia (4,000 g)	9 (6.12%)	12 (13.8%)	5 (4.90%)	3 (5.00%)	35 (9.75%)	64 (8.48%)	
Missing	77 (34.4%)	96 (52.5%)	81 (44.3%)	141 (70.1%)	340 (48.6%)	735 (49.3%)	
Gestational age at birth category. N (%)							
Preterm (36 weeks)	20 (9.05%)	16 (9.25%)	17 (9.39%)	16 (8.08%)	31 (7.21%)	100 (8.31%)	0.4
Early term (37–38 weeks)	66 (29.9%)	39 (22.5%)	56 (30.9%)	62 (31.3%)	103 (24.0%)	326 (27.1%)	
Full term (39–40 weeks)	124 (56.1%)	110 (63.6%)	92 (50.8%)	108 (54.5%)	248 (57.7%)	682 (56.7%)	
Late term (41 weeks)	<15 (6.0%)	8 (4.62%)	<20 (10.0%)	<20 (8.0%)	48 (11.2%)	95 (7.90%)	
Missing	<5 (<3%)	10 (5.5%)	<5(<3%)	<5 (<3%)	269 (38.5%)	287 (19.3%)	
In general, how distressed are you about changes to your prenatal care and/or your birth and newborn experiences due to the COVID-19 pandemic?							
Not at all	51 (24.3%)	52 (28.4%)	69 (38.3%)	116 (57.7%)	320 (52.4%)	476 (53.7%)	<0.001

Delivery dates by four pandemic periods

	February 28, 2020-June 19, 2020	June 20, 2020-September 27, 2020	September 28, 2020-January 10, 2021	January 11, 2021-May 31, 2021	Missing	Overall	p-Value
	(N=224)	(N=183)	(N=183)	(N=201)	(N=699)	(N=1,490)	
Mildly	68 (32.4%)	80 (43.7%)	80 (44.4%)	58 (28.9%)	182 (29.8%)	302 (34.0%)	
Moderately	45 (21.4%)	29 (15.8%)	<30 (< 15.0%)	<30 (<1 5.0%)	87 (14.2%)	91 (10.3%)	
Extremely	46 (21.9%)	22 (12.0%)	<10 (<5.0%)	<5 (<2.5%)	22 (3.60%)	18 (2.0%)	
Missing	33 (33.3%)	141 (35.1%)	213 (45.6%)	195 (39.1%)	88 (12.6%)	603 (40.5%)	
How has the support you receive from your prenatal care provider(s) changed due to the COVID-19 pandemic?							<0.001
Significantly worsened	7 (3.35%)	11 (6.01%)	<5(<3%)	<5 (<3%)	12 (1.97%)	13 (1.5%)	
Somewhat worsened	44 (21.1%)	28 (15.3%)	25 (13.7%)	17 (8.50%)	64 (10.5%)	95 (10.7%)	
No change	134 (64.1%)	116 (63.4%)	138 (75.8%)	160 (80.0%)	460 (75.7%)	685 (77.4%)	
Somewhat improved	16 (7.66%)	19 (10.4%)	17 (9.34%)	11 (5.50%)	43 (7.07%)	59 (6.7%)	
Significantly improved	8 (3.83%)	9 (4.92%)	<5(<3%)	<10 (5%)	29 (4.77%)	33 (3.7%)	
Missing	33 (33.3%)	143 (35.6%)	213 (45.6%)	195 (39.1%)	91 (13.0%)	605 (40.6%)	
Since becoming aware of the COVID-19 pandemic, how often have you felt happy and satisfied with your life?							<0.05
Not at all	<5 (<3%)	6 (3.64%)	<5(<3%)	<5 (<3%)	29 (4.52%)	40 (2.86%)	
Rarely	12 (5.56%)	5 (3.03%)	10 (5.52%)	8 (4.06%)	43 (6.71%)	78 (5.57%)	
Sometimes	61 (28.2%)	32 (19.4%)	27 (14.9%)	48 (24.4%)	147 (22.9%)	315 (22.5%)	
Often	82 (38.0%)	77 (46.7%)	93 (51.4%)	84 (42.6%)	276 (43.1%)	612 (43.7%)	
Very often	61 (28.2%)	45 (27.3%)	50 (27.6%)	53 (26.9%)	146 (22.8%)	355 (25.4%)	
Missing	<10 (<6%)	18 (9.8%)	<5(<3%)	<5 (<3%)	58 (8.3%)	90 (6.0%)	

Abbreviations: COVID-19, coronavirus disease 2019; SD, standard deviation.

Note. p-Values for chi-squared tests were computed across categories excluding the missing category for all categorical variables across the pandemic periods.

Table 5

Birth outcomes related to maternal answers to the question, "Please indicate the extent to which you view the COVID-19 pandemic as having either a positive or negative impact on your life"

	Negative impact (N = 1,098)			Positive or no impact (N = 383)				Overall (N=1,490)	p-Value
	Extremely negative (N=163)	Moderately negative (N=308)	Somewhat negative (N=627)	No impact (N=202)	Slightly positive (N=120)	Moderately positive (N=47)	Extremely positive (N=14)		
Gestational age at birth									
Mean (SD)	38.6 (1.82)			38.5 (2.10)				38.6 (1.90)	0.18
Median [min, max]	39.0 [23.0, 42.0]			39.0 [27.0, 42.0]				39.0 [23.0, 42.0]	
Missing	215 (19.7%)			69 (17.8%)				287 (19.3%)	
Birth weight									
Mean (SD)	3,340 (551)			3,390 (552)				3,350 (550)	0.27
Median [min, max]	3,370 [490, 5,270]			3,430 [900, 5,370]				3,400 [490, 5,370]	
Missing	540 (49.4%)			190 (49.1%)				735 (49.3%)	
Adjusted birth weight									
Mean (SD)	0.0800 (1.03)			0.268 (1.06)				0.130 (1.04)	<0.05
Median [min, max]	0.0744 [−3.21,4.11]			0.272 [−2.24, 4.32]				0.138 [−3.21, 4.32]	
Missing	540 (49.4%)			190 (49.1%)				735 (49.3%)	

n = 9 participants skipped or missed this question

Abbreviations: COVID-19, coronavirus disease 2019; max, maximum; min, minimum; SD, standard deviation.