Depression, anxiety, and stress in pregnancy and postpartum: A longitudinal study during the COVID-19 pandemic[☆]

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ABSTRACT

Introduction: Symptoms of depression, anxiety, and stress in pregnant women are generally highest in the first trimester and then decrease throughout pregnancy, reaching their lowest point in the postpartum period. Pregnant women are a high-risk population for mortality and mental health symptoms due to COVID-19. However, the extent to which the chronic stress of the COVID-19 pandemic alters the trajectory of depression, anxiety and stress symptoms in pregnant/postpartum women is unknown.
Methods: Women (N=127) who were pregnant or who had given birth less than one month prior were recruited *via* online advertising during the COVID-19 pandemic. Participants were assessed up to three times during the pregnancy and at 1-month postpartum for depression (Edinburgh Postnatal Depression Scale), anxiety, and stress (Depression, Anxiety, and Stress Scale-21). Random intercepts models examined symptom change over time as well as predictors of elevated postpartum psychopathology.
Results: On average, women completed their surveys at 8.5 weeks (first trimester), 21 weeks (second trimester), 32 weeks (third trimester) and 7-weeks postpartum. Women reported mild-moderate levels of depression, anxiety, and stress throughout pregnancy. There was a significant change in symptoms of depression and anxiety over time which was best represented by a quadratic rather than linear trajectory: symptoms increased until week 23–25 and then decreased. Stress levels remained consistently elevated over time. Higher symptom levels at 1-month postpartum were predicted by younger age, lower social support, and worry about going to a healthcare facility. Change in routine due to COVID-19 was not predictive of symptom trajectory from pregnancy to postpartum.
Conclusions: During COVID-19, symptoms of depression and anxiety increased from early to mid-pregnancy but then declined slightly while stress levels remained elevated. Observed reductions in symptoms were small. Given the substantial persistent impact of perinatal distress and poor mental health on maternal and fetal health, providers should be aware of heightened levels of these symptoms in pregnant women during large-scale external health stressors such as COVID-19, and should implement screening procedures to identify and appropriately intervene with at-risk women.

Introduction

Pregnant and postpartum women are at high-risk for morbidity, mortality and increased symptoms of poor mental health due to COVID-19 (American College of Obstetricians and Gynecologists, 2021; Westgren et al., 2021). Multiple studies have found higher levels of depression, anxiety and stress in pregnant and postpartum women during the pandemic than were reported pre-pandemic (Khoury et al., 2021; Layton et al., 2021; Lebel et al., 2020). For example, in a sample of over 1000 women across the U. S. surveyed in spring/summer of 2020 (during the pandemic), 36% of pregnant or postpartum women reported symptom levels indicative of depression, and 22% reported symptom levels indicative of generalized anxiety (Liu et al., 2021a). In comparison, pre-pandemic, 13–16% of pregnant women and 17% of postpartum women had symptom levels indicative of probable major depressive disorder (MDD) and 0.3–5.3% of pregnant women and 5.7% of postpartum women met criteria for generalized anxiety disorder (GAD; Dennis et al., 2017; Shorey et al., 2018; Wilcox et al., 2021). Persistent elevated symptoms of depression, anxiety and

stress during pregnancy and the postpartum period pose a serious maternal and fetal health risk (Dowse et al., 2020; Kordi et al., 2017; Roy-Matton et al., 2011; Tegethoff et al., 2011). Given that the COVID-19 pandemic directly affected millions of pregnancies in the United States and abroad and that researchers estimate future viral pandemics or endemics are likely, developing an understanding of pandemic influences on mental health in pregnant and postpartum women is critical (Behl et al., 2022; Telenti et al., 2021).

Symptoms of poor mental health during pregnancy are associated with increased risk of preeclampsia, birth complications, preterm birth, lower neonatal birth weight, and an increased infant hospital length of stay (Dowse et al., 2020; Kordi et al., 2017; Roy-Matton et al., 2011; Tegethoff et al., 2011). Evidence also suggests that perinatal psychopathology is related to poor social-emotional, cognitive, language, and motor development as well as increased risk for emotional problems in children (Rees et al., 2019; Rogers et al., 2020). Finally, elevated psychopathology in pregnancy and the postpartum period is associated with poor maternal mental health (including substance abuse and suicidal ideation) years after birth (Pentecost et al., 2021; Slomian et al., 2019). The COVID-19 pandemic may have dramatically increased the rates of psychopathology in pregnant and postpartum women, but the trajectory of symptoms throughout the perinatal period is unknown, a gap that impacts screening practices and intervention delivery.

In non-pandemic times, trajectory analyses of symptom change over time showed that levels of depression and anxiety tended to be highest in early pregnancy and to decrease during pregnancy, reaching their lowest points during the postpartum period (Asselmann et al., 2020; Rallis et al., 2014; Setse et al., 2009). These analyses used self-report questionnaire data, usually the Edinburgh Postnatal Depression Scale (EDPS), in large cohorts of women in high-income countries (Germany, Australia, and the United States). Symptom trajectories in pregnancy and the postpartum period during the COVID-19 pandemic have yet to be explored in a longitudinal study. It is possible that the trajectory of symptoms during COVID-19 will reflect pre-pandemic patterns (i.e., elevated in early pregnancy and a consistent decline over time). However, it is also possible that symptoms may be consistently high across both pregnancy and postpartum or that symptoms will increase over the course of pregnancy but decrease after delivery. The present paper examined the trajectory of symptoms over time during the pandemic as well as investigated risk factors for elevated postpartum symptoms.

Early cross-sectional self-report studies conducted during the pandemic in Canada and Turkey found elevated distress levels independent of gestational age, suggesting persistently elevated symptoms throughout pregnancy (Durankuş and Aksu, 2022; Khoury et al., 2021). However, one cross-sectional study of pregnant women in the U.S. found that women in their second or third trimesters were more likely to have symptoms indicative of depression and anxiety compared to women in their first trimester, potentially supporting a trend towards increasing symptoms in later pregnancy (Liu et al., 2021b). Additionally, a study of 135 U.S. women that began prior to the pandemic found that women's late-pregnancy and postpartum symptom levels during the COVID-19 pandemic were equal to or higher than symptom levels during non-pandemic early pregnancy (symptoms of depression and anxiety were assessed with the EPDS and STAI-short form respectively), indicating that the pandemic may lead to elevated symptoms during a period typically characterized by lower symptom levels (Perzow et al., 2021).

While pre-pandemic data support a substantial decline in symptoms following birth, the elevated rates of postpartum symptomatology during the COVID-19 pandemic may suggest a persistent elevation in symptoms throughout pregnancy that persists in the postpartum period (Ahmed et al., 2019; Layton et al., 2021;

Setse et al., 2009). A meta-analysis of pregnant and postpartum symptoms during the pandemic found that the prevalence of anxiety decreased throughout pregnancy but that the prevalence of depression had a "U" shaped pattern such that prevalence estimates were highest in the first and third trimester and lowest in the second trimester (Yan et al., 2020). However, all 23 of the studies included in this analysis were cross-sectional or case-control, highlighting the need for longitudinal research (Yan et al., 2020).

There are many factors (e.g., social isolation, financial stress, pregnancy-related anxiety) that may have influenced symptom trajectories for pregnant and postpartum women during the COVID-19 pandemic (Khoury et al., 2021; Liu et al., 2021a). These factors, combined with basal normative stress, may exacerbate pre-existing mental health issues or induce new symptoms of depression, anxiety, and stress. For instance, higher levels of social isolation and loneliness were associated with more symptoms of depression and anxiety in pregnant women during the pandemic in women in the U.S. and Canada (Khoury et al., 2021; Perzow et al., 2021). Unlike other forms of chronic stress, the pandemic directly impacted women's perinatal health care. Almost 60% of pregnant women in a U.S. sample of 715 participants surveyed during spring/summer 2020 reported having canceled or having had fewer medical appointments which may have led them to feel isolated and/or unprepared for birth (Liu et al., 2021b). During the pandemic, expectant mothers frequently reported worry about not having their partner in the hospital with them or worry about them or their child contracting COVID-19 in the hospital (Barbosa-Leiker et al., 2021; Burgess et al., 2022; Schaal et al., 2021). Pregnant women during the pandemic also had significantly higher fear of childbirth compared to women who were pregnant prior to the pandemic (Schaal et al., 2021). Thus, as women approached giving birth, COVID-19 related anxiety and worry may have increased, directly affecting the trajectory of mental health symptoms during pregnancy.

In addition to assessing the symptom trajectories, we also examined predictors of postpartum symptomatology. Several sociodemographic risk factors for postpartum psychopathology have been identified. Lower social support is a well-established risk factor for postpartum symptomatology (Schwab-Reese et al., 2017). Additionally, high-risk pregnancy, as defined by the presence of medical problems in the mother and/or fetus, is consistently associated with postpartum depression and anxiety (Zadeh et al., 2012). Parity and maternal age have also been found to be predictors of postpartum mental health symptoms in non-pandemic samples but the direction of these effects has been mixed (Guintivano et al., 2018; Henderson and Redshaw, 2013; Sockol et al., 2014). Additionally, COVID-19 related factors (e.g., changes in routine, isolation, uncertainty, and pregnancy-related worry) may predict postpartum symptoms and may influence the normative symptom trajectory (Medina-Jimenez et al., 2020).

Because screening for postpartum depression is recommended between 3 and 6 weeks postpartum in the U.S., we examined if social support, high risk pregnancy, parity, maternal age, changes in routine due to COVID-19, and worry about going to a healthcare facility due to COVID-19 predicted higher levels of depression, anxiety and stress one-month postpartum (American College of Obstetricians and Gynecologists, 2021; Curry et al., 2018). Based on the existent literature, we made the following hypotheses:

1. Levels of depression, anxiety, and stress will remain consistently elevated over time.
2. The trajectories of depression, anxiety and stress over time will show a curvilinear trend such that symptoms will increase from early to later pregnancy and then decrease in the postpartum period.

3. Findings will remain significant after controlling for sociodemographic and COVID-19 related factors.
4. Baseline low social support, high pregnancy risk status, high perceived changes in routine and higher levels of worry about going to a healthcare facility due to COVID-19 will significantly predict higher levels of depression, anxiety, and stress at one-month postpartum. Additionally, we hypothesized that maternal age and parity would significantly predict depression, anxiety, and stress levels one-month postpartum. As the literature is mixed on the effects of maternal age and parity on mental health symptoms, we did not hypothesize a direction for these effects.

Method

Procedure

The following procedures were approved by the [omitted for blind review] IRB (ID: 20-247). From June 15, 2020 until January 16, 2021, advertisements were posted in U.S-based Facebook groups for pregnant women and advertised on Facebook. The survey was hosted on Qualtrics. Upon clicking the advertisement, participants completed informed consent and began the study. Participants were eligible if they were currently pregnant or had given birth within the last month. Women who provided their contact information were eligible for up to three follow-up surveys based on their gestational age when they initiated participation. For example, women who completed the baseline survey in weeks 1–17 of pregnancy were eligible for the second trimester survey at 20 weeks, the third trimester survey at 29 weeks, and the postpartum survey 3 weeks post-birth. Alternatively, a woman who completed the baseline survey at 32 weeks (third trimester) would be eligible only for the postpartum survey three weeks post-birth. Due to an error, 13 individuals who completed surveys in the early second trimester (13–17 weeks) also completed an additional second trimester survey later in their trimester; one participant who started the study early in their third trimester also completed an additional third trimester survey. While this resulted in two observations in one trimester for some participants, we retained these data because our analyses used a continuous measure of gestational weeks rather than trimesters (Supplemental Table 1).

Measures

Demographic information collected included age, race, marital status, parity, smoking and alcohol use, and whether the participant lived alone. Pregnant participants self-reported their due date, current week of pregnancy, and date they learned they were pregnant. Participants who had given birth reported the date of birth. Trimesters were defined as: first trimester = 1–12 weeks, second trimester = 13–28 weeks, third trimester = 29–40 weeks (United States National Institute of Child Health and Human Development, 2017). Women also reported on perinatal care utilization, health conditions, parity, and high-risk status.

The Depression, Anxiety and Stress Scale (DASS-21), a reliable and valid 21-item self-report measure, was used to assess anxiety symptoms and stress levels over the past week at all time points (Antony et al., 1998; Sinclair et al., 2012). Internal consistency of the DASS-21 was moderately high in the current study for anxiety (Cronbach's Alpha=0.62–0.82) and stress (Cronbach's Alpha=0.82–0.89). Scores of >10 and >18 were used to indicate moderate levels of anxiety and stress, respectively (Lovibond and Lovibond, 1995). While the DASS-21 depression subscale has also been used in the perinatal period, we decided to use the Edinburgh Postnatal Depression Scale for assessing depression in accordance with current

recommendations for appropriate depression measures in pregnant women (Bryson et al., 2021; Nast et al., 2013).

The Edinburgh Postnatal Depression Scale (EPDS), a 10-item self-report measure, was used to evaluate depression levels over the past week at all four time points (Cox et al., 1987). Due to concerns regarding mandated reporting, we removed the item assessing suicidal ideation, resulting in a 9-item scale. Despite this adjustment, internal consistency of the EDPS was high in the current study (Cronbach's Alpha= 0.86–0.92). A cut-off score of 12 or 13 is typically used as an indicator of significant depression symptoms on the full EDPS (Cox et al., 1987). Because we removed an item of the EDPS, we used participants' scores on both the EPDS and the depression scale of the DASS-21 to determine which individuals could be categorized as moderately depressed. According to a large study of postpartum women in the United States, scores on the EDPS ranging from 7 to 13 were associated with mild depression, while scores of 14–19 corresponded with moderate depression; a score of 14 is also used as the indicator for moderate depression on the DASS-21 depression scale (Lovibond and Lovibond, 1995; McCabe-Beane et al., 2016). Thus, we classified women as having moderate depression if scores on both the DASS-21 and EDPS were 14 or higher. We interpreted scores in the 7–13 range as mild depression given that this range included scoring positive for a majority of the nine items. This cut off score was simply used for descriptive purposes and to examine possible differences between the present assessment and pre-pandemic; all other analyses for depression were conducted using the total score of the EDPS.

Social support was assessed at each time point using the Multidimensional Scale of Perceived Social Support (MSPSS), a 12-item measure of perceived social support from family, friends, and significant others (Zimet et al., 1988). Internal consistency was high for this measure (Cronbach's Alpha=0.94).

COVID-19 in the United States during the study

The first participant completed their first survey on July 11, 2020, and the final participant finished their final survey on June 15, 2021. Because the U.S. Centers for Disease Control (CDC) recommended breastfeeding women get vaccinated in August 2021, all participants were enrolled and completed the study prior to widespread vaccination among pregnant and breastfeeding women (Centers for Disease Control, 2021a). By September 2021 (two months after the final participant completed their final survey in our study), the CDC reported that only 31% of pregnant women were vaccinated for COVID-19 in the United States. At the time, over 22,000 pregnant women had been hospitalized with COVID-19, and 161 had died (Centers for Disease Control, 2021b), thus demonstrating the significant risk that COVID-19 posed for pregnant and postpartum women throughout the duration of our study period (Centers for Disease Control, 2021b). Importantly, the United States allowed individual states to govern their lockdown and other COVID-19 related policies, leading to significant variability in policies, timing of policy enactment, and political messaging across the nation. Such state-level differences have been associated with differences in COVID-19 related outcomes. For example, levels of depression and anxiety have been positively associated with stringency of lockdown policies; however, this relationship varied geographically as a factor of state-level economic support (Yao et al., 2022).

At each assessment, participants were asked a series of questions regarding COVID-19 restrictions, perceived impact of the pandemic on a participant's life, (shown in Supplemental Table 2). For the current analysis, we used participants' responses to "Covid-19 has changed my daily routine" to capture the perceived impact of COVID-19 restrictions. To address healthcare related anxiety during the pandemic, participants were asked to rate their worry (1=Not

at all worried- 7=Extremely worried) about going to a medical facility for the following: (1) a routine prenatal checkup, (2) a serious medical problem, (3) giving birth, and (4) a routine check-up for your infant. Responses to the four healthcare worry items were averaged to create an index of overall healthcare worry. This study was designed in Spring 2020 and was thus initiated prior to creation of standardized COVID-19 stress measures.

Statistical analyses

Analyses were conducted with Stata Version 16.1 using restricted maximum likelihood estimation for mixed models (StataCorp, 2019). Hypothesis one was tested with a random-intercepts only model predicting scores for anxiety, depression, and stress from the centered time variable. To determine if a quadratic model best fit the data, we calculated the deviance statistic between the linear and curvilinear model and compared it to the Chi Square Statistic ($\chi^2(1)$=6.63, p<0.01). For hypotheses one and two, time was treated as a continuous variable scaled from 0 to 2 such that 0 indicated conception (40 weeks pre-birth), 1 indicated birth, and 2 indicated 40 weeks post-birth. The scaled period of interest ranged from 0 to approximately 1.12, as we were concerned with outcomes at one-month postpartum. Random-intercepts models for social support, the extent to which COVID-19 changed daily routines, and amount of worry about going to healthcare facilities did not vary over time: thus, baseline levels were used as predictors (Supplemental Table 3). The following predictors were used in the model: parity, high risk status, age, social support, worry about going to healthcare facilities, and change in routine due to COVID-19. For hypothesis four, we centered time such that zero was 4 weeks postpartum; this enabled the regression coefficients to be interpreted as differences in the outcomes at one-month postpartum. Participants who were missing more than 20% (typically 1–4 items) of an instrument were considered missing the entire instrument. If 20% or fewer items were missing, the mean score of the completed items was used for the missing item(s).

Power analysis

A post-hoc power analysis was conducted in G*Power for a repeated measures ANOVA, within factors test (Faul et al., 2007). Based on prior literature, we identified an effect size of 0.2 (Kim, 2016; Rallis et al., 2014). Assuming an alpha error probability of 0.05, 1 group, 4 measurements and a 0.6 correlation among repeated measures (as determined by calculating the inter-class coefficient of the multilevel model) for a sample of 150, the post-hoc power analysis yielded a power of 0.99, indicating that the current sample is well-powered to detect small effects.

Results

Retention

A total of 307 participants clicked the link to begin informed consent; one person clicked but did not consent. As is common with online studies, only a portion of participants who clicked the advertised study link participated past the initial consent. A total of 150 participants provided sufficient usable data at baseline for the outcomes of the study. Of the 157 with incomplete data, the majority did not provide their email addresses (76%), did not provide sufficient information to calculate their gestational age (81%), and/or did not continue beyond the demographics portion of the survey (72%). Seventeen of the 150 eligible participants at baseline had already given birth, and 7 of the pregnant eligible participants

did not provide an email address resulting in 126 pregnant participants eligible for follow ups. Among the eligible participants at each time point, 65% were retained at the second trimester, 53% at the third trimester, and 49% at the one-month postpartum survey (Supplemental Table 1). Overall, six participants completed all four possible time points (with an additional six participants who had four observations due to completing the survey twice during the second trimester). Twenty-four participants completed three time points, 45 completed two timepoints, and 69 completed only the baseline timepoint, resulting in 150 participants in the analyses of symptom change over time. When the predictors for hypotheses two and three were added, the sample size reduced to 127 participants due to missing data.

Table 1
Participant demographics.

	N	%
Race (N=149)		
White	122	80.79
Black	3	1.99
Hispanic/Latino	9	5.96
Native American	1	0.66
Asian	1	0.66
Multiracial	13	8.72
Marital Status (N=149)		
Married	109	73.15
In a relationship	32	21.48
Single	6	4.03
Divorced	1	0.67
Other	1	0.67
Age (N=145)		
18–23	23	15.86
24–29	65	44.83
30–35	41	28.28
36–41	16	11.03
U.S. Region (N=140)		
Northeast	12	8.57
Midwest	57	40.71
South	41	29.29
West	30	21.43
How often do you leave your home for work related reasons? (N=149)		
Daily/Essential Employee	49	32.89
Daily/Non-essential employee	10	7.14
Weekly	15	10.10
Monthly	6	4.29
Never	70	47.0
High Risk (N=140)		
Yes	44	31.4
No	96	68.6
First Pregnancy (N=141)		
Yes	73	51.7
No	68	48.2
Birthed multiples (N=141)		
Yes	1	1.00
No	140	99.0
Condition present at baseline		
Hypertensions duringpregnancy/preeclampsia	9	NA
Diabetes (gestational diabetes)	15	NA
Smoked during pregnancy (Baseline) (N=141)		
Never	125	88.65
Rarely	4	2.84
Sometimes	8	5.67
Often	3	2.13
Always	1	.71
Alcohol during pregnancy (Baseline)		
Never	129	91.49
Rarely	12	8.51
Sometimes	0	0
Often	0	0
Always	0	0

Table 2
Mean levels of depression, anxiety and stress across trimesters.

	N	Mean (SD)	N (%) with Moderate Symptoms
Depression			
Trimester 1	28	9.18 (4.67)	3 (10.71%)
Trimester 2	91	10.66 (5.18)	23 (25.30%)
Trimester 3	76	10.59 (5.85)	17 (22.37%)
1-month post-partum	83	9.10 (5.91)	16 (19.30%)
Anxiety			
Trimester 1	28	9.21 (8.21)	10 (35.71)
Trimester 2	91	10.88 (7.19)	48 (52.75%)
Trimester 3	76	11.72 (9.40)	40 (52.63%)
1-month post-partum	83	8.19 (8.71)	26 (31.33)
Stress			
Trimester 1	28	15.21 (8.53)	9 (32.14%)
Trimester 2	91	19.32 (9.52)	44 (48.35%)
Trimester 3	78	19.36 (11.41)	37 (47.44%)
1-monthpost-partum	83	16.55 (11.49)	27 (32.53%)

Note: N=150

Descriptive statistics

The final sample consisted of pregnant and postpartum women aged 19–40 (M= 28.8 SD=5.12). Most participants were white (81%), married (73%) and were from either the Midwest (41%) or Southern (30%) United States, although participants represented 40 different states (Table 1). Fifty-two percent of women were primiparous, and 31% were high-risk pregnancies. At baseline, average ratings of COVID-19 restrictions were high (Supplemental Table 2). Most women gave birth in a hospital, and 24% had a c-section (Supplemental Table 4). There were no differences between participants who only completed the baseline survey and those who completed multiple surveys on demographics, initial levels of psychopathology, or COVID-19 variables (Supplemental Table 5). Descriptive statistics for depression, anxiety, and stress across trimesters are reported in Table 2.

Hypothesis one: symptoms will remain consistently elevated over time

On average, women completed their surveys at 8.5 weeks (SD=2.52; first trimester), 21 weeks (SD=3.2; second trimester),

32 weeks (SD=3.7; third trimester) and 7 weeks postpartum (SD=5.1). There was a significant decline in symptoms of depression (B=−1.71, SE=0.81, z=−2.1, p=0.036) and anxiety (B=−3.03, SE=1.30, z=−2.33, p=0.02; Table 3) from the trimester through one-month postpartum. Stress remained consistently elevated over time (B=−2.13, SE=1.55, z=−1.37, p=0.17).

Hypothesis two: symptoms will show a curvilinear trajectory

The change in symptoms was best explained by a quadratic rather than linear trajectory for depression (B=−5.90, SE=2.18, z=−2.71, p=0.01), anxiety (B=−8.55, SE=3.46, z=−2.47, p=0.013), and stress (B=−10.19, SE=4.17, z=−2.44, p=0.015; Table 3). While significant, these symptom changes were relatively small, with questionable clinical relevance (see Table 2). Fit lines for linear and curvilinear trajectories are shown in Figure 1.

Hypothesis three: symptom trajectories will remain significant after controlling for sociodemographic and COVID-19 factors

When covariates were added to the quadratic model of symptoms from pregnancy through one-month postpartum, the quadratic term remained significant for depression (B=−6.63, SE=2.58, z=−2.57, p=0.01) and anxiety (B=−9.32, SE=4.09, z=−228, p=0.02; Table 4). Symptoms of depression began decreasing when time=0.63 for depression (approximately 25 weeks of gestation) and time=0.58 for anxiety (approximately 23 weeks of gestation). The rate of change for depression was 0.17 points per week and 0.23 points per week for anxiety. When controlling for covariates, both the curvilinear (B=−8.91, SE=4.96, z=−1.80, p=0.07) and the linear (B=11.24, SE=7.59, z=1.48, p=0.14) trajectory for stress were not significant, indicating that stress symptoms remained elevated over time.

Hypothesis four: risk factors for elevated symptoms postpartum

Younger age and lower social support significantly predicted higher depression, anxiety, and stress one-month postpartum (Table 5). Higher worry about going to a healthcare facility predicted higher one-month postpartum depression (B=0.83, SE=0.31, z=2.68 p=0.007), anxiety (B= 1.99, SE: 0.49, z=4.02, p<0.001), and stress (B= 2.11, SE: 0.61, z=0.06, p<0.001). Change in routine due

Table 3
Linear and quadratic change in depression, anxiety and stress in pregnancy and one-month postpartum.

Effect	Parameter	Depression		Anxiety		Stress	
		Model 1 Fixed effects	Model 2	Model 1	Model 2	Model 1	Model 2
Intercept	γ_{00}	11.56 (0.76) p<0.001	8.73 (1.30), p<0.001	13.01 (1.20) p<0.001	8.95 (2.07)	20.20 (1.46) p<0.001	15.26
Time	β_1	−1.71 (0.81) p=0.036	7.44 (3.48), p=0.033	−3.03 (1.30), p=0.020	10.17 (5.54) p=0.07	−2.13 (1.55) p=0.17	13.71 (6.67) p=0.04
Time^2	β_2		−5.90 (2.18), p=0.007		−8.55 (3.46) p=0.01		−10.19 (4.17) p=0.02
		Random effects					
Variance Components							
Level 1	σ_{ϵ}^2	12.17 (1.52)	11.42 (1.45)	31.86 (4.17)	29.89 (3.95)	43.83 (5.52)	42.52 (5.36)
Level 2	σ_0^2	19.64 (3.36)	20.52 (3.43)	45.89 (8.75)	48.71 (8.97)	74.83 (12.75)	74.05 (12.64)
		Goodness of fit					
Deviance		1682.88	1672.41	1950.73	1940.57	2057.69	2047.09
$\Delta\chi^2$		10.47	10.16	10.60			
Δdf		1	1	1			

Note. N=150 Random intercepts models of depression, anxiety, and stress over time. Time is centered such that zero indicates conception and 1 is 40- weeks pregnant.
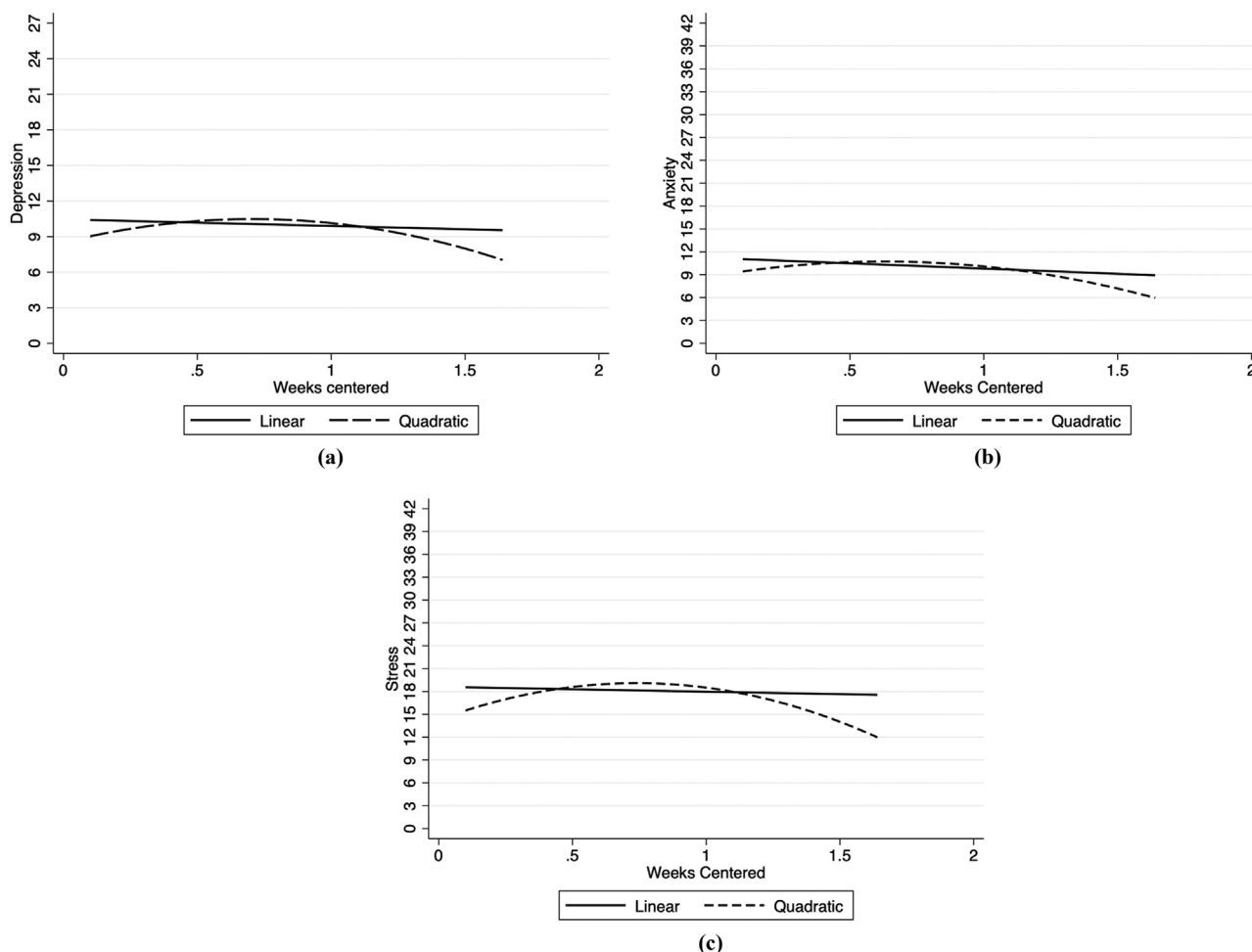
Fig. 1. a. Fit Lines for Linear and Quadratic Models for Depression 1b: Fit Lines for Linear and Quadratic Models for Anxiety 1c: Fit Lines for Linear and Quadratic Models for Stress _1a-c Legend:_ Dashed lines indicate the quadratic trajectory of symptom change over time and the solid lines indicate the linear trajectory. Weeks are centered such that 1= 40 weeks and 0 indicates conception.

Table 4
Quadratic change in depression, anxiety and stress over time, controlling for covariates.

Effect	Parameter	Depression	Anxiety	Stress
		Fixed Effects		
Intercept	γ_{00}	19.39 (3.52)	22.44 (5.61)	36.69 (6.85)
		$p<0.001$	$p<0.001$	$p<0.001$
Time	β_1	8.41 (3.94)	10.94 (6.26)	11.24 (7.59)
		$p=0.033$	$p=0.08$	$p=0.14$
Time^2	β_2	−6.64 (2.58)	−9.32 (4.09)	−8.91 (4.96)
		$p=0.01$	$p=0.023$	$p=0.07$
Social Support	β_3	−1.51 (0.34)	−1.195 (0.54)	−2.08 (0.66)
		$p<0.001$	$p<0.001$	$p=0.002$
Age	β_4	−0.25 (0.34)	−0.39 (0.14)	−0.60 (0.17)
		$p=0.004$	$p=0.005$	$p<0.001$
High Risk	β_5	1.67 (0.84)	1.59 (1.34)	1.07 (1.64)
		$p=0.047$	$p=0.24$	$p=0.51$
First Pregnancy	β_6	0.53 (0.84)	1.78 (1.34)	.92 (1.64)
		$p=0.53$	$p=0.19$	$p=0.58$
Change in routine due to COVID-19	β_7	0.20 (0.45)	−0.09 (0.72)	.05 (0.88)
		$p=0.66$	$p=0.91$	$p=0.95$
Health Care Facility Worry	β_8	0.84 (0.31)	2.0 (0.50)	2.11 (0.61)
		$p=0.007$	$p<0.001$	$p=0.001$
		Random Effects		
Variance Components				
Level 1	σ_ϵ^2	11.18 (1.41)	28.48 (3.70)	41.71 (5.30)
Level 2	σ_0^2	13.74 (2.71)	34.97 (7.33)	52.69 (10.60)

Note. N=127 Time is centered such that zero indicates conception and 1 is 40 weeks pregnant.

Table 5
Prediction of postpartum symptomatology.

Effect	Parameter	Depression	Anxiety	Stress
		Fixed Effects		
Intercept	γ_{00}			
Time	β_1	−0.11 (0.04)	−0.19 (0.06)	−0.16 (0.07)
		$p=0.002$	$p=0.001$	$p=0.02$
Time^2	β_2	−0.003 (0.001)	−0.004 (0.002)	−0.005 (0.003)
		$p=0.02$	$p=0.023$	$p=0.07$
Social Support	β_3	−1.51 (0.34)	−1.95 (0.54)	−2.07 (0.66)
		$p<0.001$	$p<0.001$	$p=0.002$
Age	β_4	−0.25 (0.09)	−0.39 (0.14)	−0.60 (0.17)
		$p=0.004$	$p=0.005$	$p<0.001$
High Risk	β_5	1.69 (0.84)	1.60 (1.34)	1.08 (1.64)
		$p=0.045$	$p=0.23$	$p=0.51$
First Pregnancy	β_6	0.54 (0.84)	1.78 (1.34)	0.93 (1.64)
		$p=0.52$	$p=0.19$	$p=0.57$
Change in routine due to COVID-19	β_7	0.20 (0.45)	−0.07 (0.72)	0.06 (0.88)
		$p=0.65$	$p=0.92$	$p=0.94$
Health Care Facility Worry	β_8	0.83 (0.31)	2.0 (0.50)	2.11 (0.61)
		$p=0.007$	$p<0.001$	$p=0.001$
		Random Effects		
Variance Components				
Level 1	σ_ϵ^2	11.22 (1.41)	28.31 (3.66)	41.65 (5.29)
Level 2	σ_0^2	13.62 (2.70)	34.31 (3.66)	52.44 (10.53)

Note. N=127. Time was centered such that zero indicates four weeks postpartum. Regression coefficients can be interpreted the relationship between symptom levels and predictors at 4-weeks post-birth.

to COVID-19 was not predictive of symptoms one-month postpartum and neither was pregnancy risk or parity.

Discussion

To our knowledge, this is the first study to model changes in depression, anxiety, and stress throughout pregnancy and one-month postpartum during the COVID-19 pandemic. Consistent with pre-pandemic and pandemic literature showing a decline in symptoms in late pregnancy and in the postpartum period (Asselmann et al., 2020; Gonzalez-Garcia et al., 2021; Rallis et al., 2014), we found that the trajectory of anxiety and depression symptoms was best represented by a quadratic curve whereby symptoms increased in early pregnancy and then began decreasing around week 25 for depression and week 23 for anxiety. However, even with the overall reduction in symptoms, more than 30% of women reported at least moderate symptoms of anxiety and 19% reported at least moderate depression one-month postpartum, which is higher than pre-pandemic estimates from meta-analyses (Dennis et al., 2017; Shorey et al., 2018). Additionally, the reduction in symptoms over time was small and may not represent a clinically significant change. In contrast to results concerning anxiety and depression, stress levels remained consistently elevated over time, underscoring a persistent impact of the pandemic across pregnancy and the postpartum period.

We also observed a pattern of increasing symptoms in the second trimester; this has not been typically observed in pre-pandemic studies. COVID-19 related disruptions in routine perinatal care such as canceled or virtual appointments during the second trimester may have led to more perceived stress. Alternatively, lack of social support may have contributed. Because the risk of miscarriage drops in the second trimester, many expectant mothers wait to disclose their pregnancy at this time (Tong et al., 2008). However, social distancing may have prevented expectant mothers from receiving traditional forms of support such as prenatal classes or baby showers. Interestingly, we observed a decline in symptoms at approximately 23–25 weeks, or the beginning of the third trimester. By this time, expectant mothers may have adjusted to pandemic circumstances resulting in symptom levels more similar to pre-pandemic studies. These results underscore the impor-

tance of mental health screening and intervention in early-mid pregnancy especially during a major public health crisis.

Because the postpartum period is a critical period for new mothers, we also examined risk factors for depression, anxiety, and stress one-month postpartum. Increased worry about going to a healthcare facility for a pregnancy-related visit significantly predicted postpartum depression and anxiety. Unexpectedly, the extent to which COVID-19 changed participants' routines was not a significant predictor of mental health outcomes. This may be due to a ceiling effect, as 86% of participants reported that they "agreed" or "strongly agreed" with the statement "COVID-19 has changed my daily routine." While this indicates that women in our study experienced COVID-19 as a major disruption, our results demonstrate that perceived worry and fear was more predictive of mental health outcomes than COVID-related disruptions.

Results also indicated that younger participants had more symptoms in the first trimester and one-month postpartum, which is consistent with some pre-pandemic research and may reflect the challenges of being a young parent (Bottino et al., 2012; Ahmed et al., 2018). Finally, our results supported our hypothesis that having lower levels of social support would predict higher postpartum depression, anxiety, and stress (Ahmed et al., 2018; Bottino et al., 2012; Iyengar et al., 2021).

These results suggest that large-scale external health stressors such as the COVID-19 pandemic can result in higher levels of mental health symptoms in pregnant and postpartum women, and that providers should continue to screen for symptoms in each trimester as well as into the postpartum period and provide resources for those at greater risk. This finding may be particularly important in countries such as the United Kingdom where perinatal depression screening is not yet recommended and struggling pregnant women may not be identified (Solutions for Public Health, 2019). Regardless of screening practices, these findings suggest that pandemic preparedness must include provisions for additional mental health support for pregnant and postpartum women.

This study is not without limitations. First, is the extent to which the present study generalizes to all pregnant women. In the present sample, 31% of participants were classified as high-risk pregnancies, a rate higher than U.S. prevalence rates (that range from 3.5% for multiple births, to 7.3% for diabetes, 8.5%

for hypertensive disorder, and 17.6% for women older than 35; National Academies of Sciences, Engineering, and Medicine, 2020). Although classification of a high-risk pregnancy was not associated with differences in levels of psychopathology during the first trimester or one-month postpartum, it is possible that results would not generalize to pregnant women who do not visit online postings regarding pregnancy or participate in online studies. Additionally, as we were unable to examine race/ethnicity as predictors of perinatal psychopathology, it is possible that results would not generalize to women of all races/ethnicities. It is also important to note that pre-pandemic estimates for postpartum mental health symptoms were based on large-scale international meta-analyses and studies (Asselmann et al., 2020; Dennis et al., 2017; Rallis et al., 2014; Setse et al., 2009; Shorey et al., 2018) and our sample only included U.S residents.

We also had a limited number of women who entered the study in their first trimester. This may be because women generally do not realize that they are pregnant until around 5.5 weeks (later for women with an unintended pregnancy; Branum and Ahrens 2017). While we had at least 49% retention of people who were eligible for each time point, the average participant completed only two time points, which may have limited our ability to detect smaller within-subjects changes in symptoms over time.

Due to the changing nature of the pandemic, it is possible that observed results may be reflective of local changes in lockdowns, available treatments and medications, and COVID-19 policies. However, we found that participants' ratings of the phrase "Covid-19 has changed my daily routine" did not change over time, suggesting that participants' experience of the pandemic restrictions were relatively stable over the course of our study. Further, controlling for ratings of this phrase did not impact the trajectory of depression and anxiety symptoms although the change in stress ratings did become nonsignificant.

Finally, removal of the suicide item from the EDPS may have limited the reliability and validity of this scale. While suicide is a major risk in pregnant and postpartum women, evidence suggests that suicidal ideation is highly associated with other symptoms of depression and psychosocial stress. Thus it is unlikely that the removal of this item substantially impacted the proportion of participants meeting cut off for moderate-severe symptoms (because participants who would have endorsed the suicidal ideation item would likely endorse enough other symptoms to meet the cut-off for moderate-severe symptoms: Gavin et al. 2011). Nevertheless, future research should examine the impact that the COVID-19 pandemic had on suicidal ideation in pregnant and postpartum women.

Despite these limitations, the present study is the first to longitudinally analyze depression, anxiety, and stress through pregnancy and postpartum during the COVID-19 pandemic. As researchers expect that not only will COVID-19 continue to evolve and spread but that there are a number of other viruses that may lead to pandemics or endemics (Behl et al., 2022; Telenti et al., 2021), providers, policy makers, and researchers should consider how to improve mental health for obstetric patients during health crises. This can be accomplished by implementing regular screening practices, coordinating care and referrals for individuals with high levels of symptoms, promoting online interventions, or increasing virtual social support (Potharst et al., 2022; Puertas-Gonzalez et al., 2021; Suwalska et al., 2021). Incorporating these strategies pre-emptively may prevent negative maternal and fetal outcomes in future pandemics.

Declaration of Competing Interest

None.

CRediT authorship contribution statement

Emily P. Rabinowitz: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Project administration. **Lindsay A. Kutash:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Project administration. **Alexis L. Richeson:** Writing – original draft, Writing – review & editing, Formal analysis. **MacKenzie A. Sayer:** Conceptualization, Methodology, Writing – review & editing. **Marielle R. Samii:** Conceptualization, Methodology, Writing – review & editing, Project administration. **Douglas L. Delahanty:** Conceptualization, Methodology, Writing – review & editing, Supervision.

Ethical Approval

This study was approved by the Kent State University IRB.

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