Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

Sleep Health 8 (2022) 175–182

Contents lists available at ScienceDirect

Sleep Health

Journal of the National Sleep Foundation

journal homepage: sleephealthjournal.org

Postpartum sleep health in a multiethnic cohort of women during the COVID-19 pandemic in New York City

Maristella Lucchini, PhD[a], Margaret H. Kyle, BA[b], Ayesha Sania, PhD[a], Nicolò Pini, PhD[a], Vanessa Babineau, PhD[d], Morgan R. Firestein, PhD[a], Cristina R. Fernández, MD[b], Lauren C. Shuffrey, PhD[a], Jennifer R. Barbosa, MA[a,b,c], Cynthia Rodriguez, BA[c], William P. Fifer, PhD[a,c], Carmela Alcántara, PhD[e], Catherine Monk, PhD[a,c,d], Dani Dumitriu, MD, PhD[a,b,f*]

[a] Division of Developmental Neuroscience, Psychiatry Department, Columbia University Irving Medical Center, New York, New York, USA
[b] Division of Child and Adolescent Health, Department of Pediatrics, Columbia University Irving Medical Center, New York, New York, USA
[c] New York State Psychiatric Institute, New York, New York, USA
[d] Department of Obstetrics and Gynecology, Columbia University Irving Medical Center, New York, New York, USA
[e] School of Social Work, Columbia University, New York, New York, USA
[f] Sackler Institute, Zuckerman Institute, and the Columbia Population Research Center, Columbia University, New York, New York, USA

ARTICLE INFO

Keywords:
COVID-19
race
ethnicity
disparities
mother
postpartum

ABSTRACT

Objective/Design: Cross-sectional study to examine the determinants of sleep health among postpartum women during the COVID-19 pandemic in New York City (NYC).
Setting/Participants: A subset of participants recruited as part of the COVID-19 Mother Baby Outcomes (COMBO) cohort at Columbia University (N = 62 non-Hispanic White, N = 17 African American, N = 107 Hispanic).
Measurements: Data on maternal sleep, COVID-19 infection during pregnancy, sociodemographic, behavioral, and psychological factors were collected via questionnaire at 4 months postpartum. Self-reported subjective sleep quality, latency, duration, efficiency, disturbances, and daytime dysfunction were examined as categorical variables (Pittsburgh Sleep Quality Index [PSQI]). Associations between sleep variables and COVID-19 status, time of the pandemic, sociodemographic, behavioral, and psychological factors were estimated via independent multivariable regressions.
Results: Mothers who delivered between May-December 2020, who delivered after the NYC COVID-19 peak, experienced worse sleep latency, disturbances and global sleep health compared to those who delivered March-April 2020, the peak of the pandemic. Maternal depression, stress and COVID-19-related post-traumatic stress were associated with all sleep domains except for sleep efficiency. Maternal perception of infant's sleep as a problem was associated with worse global PSQI score, subjective sleep quality, duration, and efficiency. Compared to non-Hispanic White, Hispanic mothers reported worse global PSQI scores, sleep latency, duration and efficiency, but less daytime dysfunction.
Conclusions: These findings provide crucial information about sociodemographic, behavioral, and psychological factors contributing to sleep health in the postpartum period.
© 2021 National Sleep Foundation. Published by Elsevier Inc. All rights reserved.

Introduction

The postpartum period poses unique challenges to mothers with respect to maintaining good sleep health.[1] Postpartum women experience significant sleepiness, shorter sleep duration, sleep fragmentation and longer periods awake after sleep onset compared to pregnant or nonpostpartum women with children.[1-6] Poor sleep during the postpartum period is associated with numerous maternal physical and psychological outcomes, such as changes in interpersonal relationships, risk of postpartum weight retention, poorer neurobehavioral performances and perinatal mood disorders.[2,7,8] While childcare demands heavily shape maternal sleep in this delicate period,[9] a vast literature has depicted a more complicated picture, with several individual and environmental factors interacting and playing significant roles in postpartum maternal sleep, such as depression,[7] social support and sleep environment.[3,10]

*Corresponding author: Dani Dumitriu, Pardes Rm 4932, 1051 Riverside Dr., New York, NY 10032, USA
E-mail address: dani.dumitriu@columbia.edu (D. Dumitriu).

https://doi.org/10.1016/j.sleh.2021.10.009
2352-7218/© 2021 National Sleep Foundation. Published by Elsevier Inc. All rights reserved.

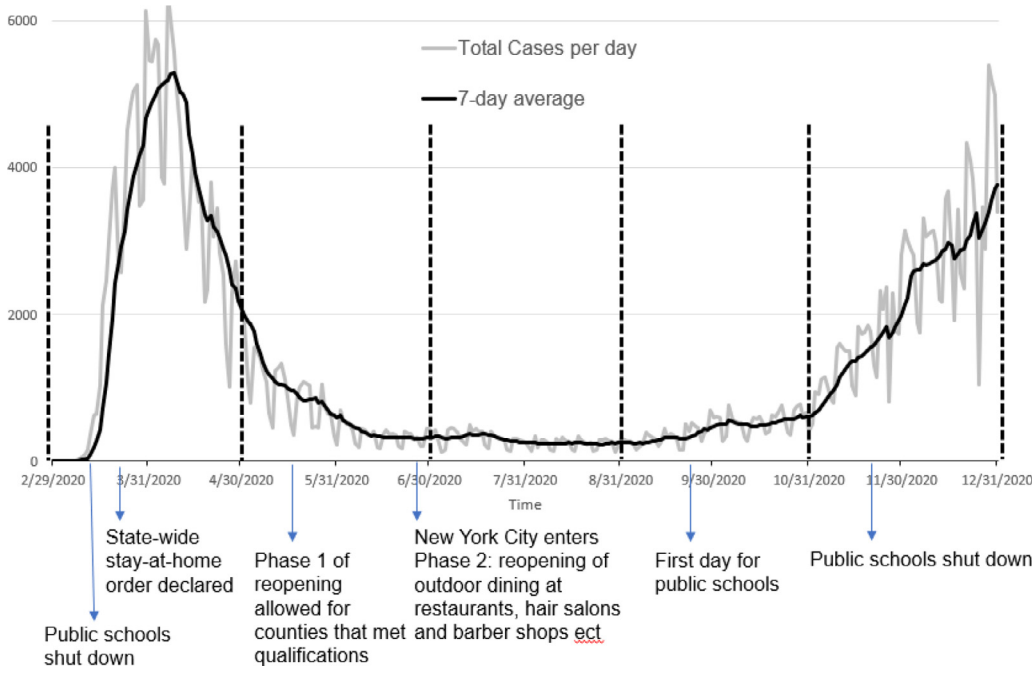

Fig. 1. In this figure, we report in gray total cases per day from March 1, 2020 to January 1, 2021. In black the 7-day average of the cases. Vertical dashed black lines identify the pandemic time bins utilized in our analyses. At the bottom, we indicate some major changes in the management of the COVID-19 pandemic in NYC. Data for this figure were obtained from https://www1.nyc.gov/site/doh/covid/covid-19-data-trends.page#epicurve.

Recent studies have highlighted the impact of the coronavirus disease 2019 (COVID-19) pandemic on sleep health.[11] The COVID-19 outbreak led to lockdowns and social distancing requirements throughout the world to mitigate the spread of the virus, affecting profoundly normal life routines crucial for circadian cues, such as physical activity, light exposure or social interaction.[11,12] In addition, health and economic insecurity led to unprecedented levels of stress,[13] which is known to negatively impact sleep.[14] On the other hand, working from home gave some people the flexibility to adapt their sleep schedules or have extra time to dedicate to beneficial activities such as exercise.[15,16] Adding to this already complex landscape, in NYC, the COVID-19 pandemic has been a very dynamic process with a first dramatic peak in the beginning of March 2020 that led to a drastic lockdown, followed by a period of reopening during the summer of 2020 and a second peak in the Fall of 2020. Major pandemic-related milestones in NYC are highlighted in Fig. 1. While many reports investigating sleep during the first lockdown period found sleep improvements, with increased sleep duration,[17,18] other studies looking at longer time windows after the COVID-19 outbreak found mixed effects.[19,20] Thus, further investigation looking at the relationship between the dynamic changes of the COVID-19 pandemic and sleep profiles is warranted.

In addition, COVID-19-related stressors have disproportionately affected individuals from race/ethnic minority communities.[21] It is known from the literature that even before the pandemic, the burden of poor sleep health was not experienced equally across the US population, with individuals from racial/ethnic minority backgrounds experiencing worse sleep health,[22,23] and the current pandemic may be exacerbating preexisting disparities in sleep health.[24]

New mothers are at particular risk of experiencing high levels of stress due to this pandemic, given the alteration of perinatal medical services and dramatic changes in social support, which may impact sleep habits and health. Nonetheless, to our knowledge, no published empirical study has investigated postpartum maternal sleep health during the COVID-19 pandemic.

In this study, we leverage a subset of the data collected for the COVID-19 Mother Baby Outcomes (COMBO) Initiative at Columbia University Irving Medical Center (CUIMC). COMBO has enrolled a racially and ethnically diverse cohort of women that have given birth since the start of the pandemic (March 2020) in NYC, an early epicenter of the COVID-19 pandemic in the United States. The overarching goal of COMBO is to broadly understand the impact of both SARS-CoV-2 infections and the pandemic on the developing fetus, future child health, and future maternal health. In particular, the aim of the study presented in this manuscript is to investigate whether maternal severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection during pregnancy, time of the pandemic, sociodemographic, behavioral, and psychological factors are associated with postpartum sleep health. The findings of this study will provide crucial information about sociodemographic, behavioral, and psychological factors contributing to sleep health in the postpartum period, highlighting potential targets to improve maternal sleep.

Participants and methods

Participants were recruited as part of the COMBO Initiative at CUIMC (www.ps.columbia.edu/COMBO), which aims to comprehensively describe the health of mother-infant dyads during the COVID-19 pandemic. Eligible mothers delivered at one of two CUIMC-affiliated NewYork-Presbyterian Hospitals: the Morgan Stanley Children's Hospital or the Allen Hospital in NYC. Study procedures were approved by the CUIMC Institutional Review Board (IRB) and informed consent was obtained from all participants.

Detailed information on recruitment can be found in the Supplementary Material. All surveys were self-administered online through a CUIMC REDCap system (version 10.6.2) and participants were offered the option to complete them in English or Spanish. Additional information was obtained from the electronic health record. In this study, we included 232 participants from the COMBO cohort who

delivered between March 2020 and December 2020 and completed the relevant surveys.

Sleep and mental health measures

The primary outcome was mothers' report of their sleep health as measured by the Pittsburgh Sleep Quality Index (PSQI) questionnaire (Cronbach's alpha 0.83 in English,[25] 0.8 in Spanish[26]) at 4 months postpartum. From the PSQI, we extracted the following measures: (1) subjective sleep quality, (2) sleep latency, (3) sleep duration at night, (4) sleep efficiency, (5) sleep disturbances, (6) use of sleep medication, and (7) daytime dysfunction. The 7 sleep domains were analyzed as categorical variables, ranging from 0 to 3 as per the PSQI scoring guidelines.[25] A global score was calculated as the sum of all items and the cut off of 5, as indicated in the literature, was used to identify a binary variable of global poor sleep (PSQI score >5) vs. global adequate sleep (PSQI score <=5).

Mothers also completed the Brief Infant Sleep Questionnaire (BISQ) from which we extracted information on the sleep environment (sleeping in separate rooms, share the room with the baby but in separate beds, and bedsharing) and on maternal perception of infant's sleep as a problem at 4 months postpartum. In addition, mothers completed the Patient Health Questionnaire-9 (PHQ-9, Cronbach's alpha 0.85)[27] to assess severity of depressive symptoms, the Perceived Stress Scale (PSS, Cronbach's alpha 0.82)[28] to assess levels of perceived stress, and the post-traumatic stress PTSD Checklist for DSM-5 (PCL5) adapted for COVID-19 (see Supplementary Material for this adapted scale) at 6 months postpartum. Mothers also self-reported if they were breastfeeding mostly or exclusively, partially or utilizing mostly or exclusively formula.

Sociodemographic and health measures

As part of hospital intake records, mothers self-reported their ethnic background as "non-Hispanic," "Hispanic," or "decline to answer" and were also asked to specify their racial background choosing from categories recommended by the National Institutes of Health (NIH) as "White," "Black or African American," "Asian," "American Indian or Alaskan Native," "Native Hawaiian or other Pacific Islander," and/or "Other." We combined the race and ethnicity variables to obtain one single race/ethnicity variable as follows: non-Hispanic White, African American, Hispanic, and Other. We also extracted from the electronic health record information on infant sex, mode of delivery, gestational age at delivery, maternal age at delivery, and health insurance status (commercial versus public [Medicaid]). We defined maternal COVID-19 status as positive if the electronic health record indicated that the participant had tested positive by PCR at any point during pregnancy or at the time of universal testing upon admission to the Labor and Delivery (L&D) unit, or tested positive by serology at universal testing upon admission to L&D and had a documented or suspected history of COVID-19 during pregnancy. Time periods of the pandemic at delivery were grouped in 2 months bins based on delivery date: (1) March-April 2020 (N = 22), (2) May-June 2020 (N = 41), (3) July-August 2020 (N = 63), (4) September-October 2020 (N = 67), and (5) November-December 2020 (N = 39). The decision of utilizing these time periods was to capture major changes in the progression of the pandemic in NYC, while guaranteeing a reasonable sample size. Fig. 1 provides an infographic of major events related to the COVID-19 pandemic in NYC from March to December 2020.

Statistical analysis

We first ran univariate analyses between all sleep domains and the following predictors: infant sex, gestational age at delivery, mode of delivery, COVID-19 status, time of pandemic, PSS, PHQ-9, PCL5, race/ethnicity, insurance status, breastfeeding, maternal perception of child sleep and sleep environment. All predictors with a $p \leq .2$ in the univariate analyses were retained for inclusion in a multivariate ordinal model for each sleep domain. Due to collinearity between mental health variables (Pearson coefficients: PHQ9 and PSS r = 0.6; PHQ9 and PSS r = 0.5), PHQ9 was selected as the primary mental health variable to be included in all multivariate models. To obtain their individual estimates, separate models were then run with PSS and PCL5 (substituting PHQ9) if they were significant in the univariate analyses. All analyses were run using R 4.0.4.

Results

Study sample characteristics

Mothers included in this analysis gave birth between March and December 2020, and questionnaires with data presented in these analyses were completed at 18.4 ± 1.9 weeks postpartum between July 2020 and April 2021. Mothers were on average 32.1 ± 5.3 years of age and the racial/ethnic composition of the sample was n = 62 (26.7%) non-Hispanic White, n = 17 (7.3%) African American, n = 107 (46.1%) Hispanic, and n = 46 (19.8%) Other. Fifty-eight percent of the mothers had commercial health insurance and 38.4% had an electronic health record documented COVID-19 diagnosis during pregnancy. Two-thirds of the mothers slept in the same room of their infants but in separate beds, while 17.2% slept in separate rooms and 7.3% practiced bedsharing. Sixty-nine percent of the mothers did not perceive their infant's sleep as a problem, while 30% did perceive it as a moderate/severe problem. Additional demographics are presented in Table 1. Twenty-four percent of the women rated their sleep as fairly bad or very bad, more than half slept fewer than the recommended 7 hours of sleep per night (57.3%) and 66% took longer than 15 minutes to fall asleep. Fifty-nine percent of the women had a sleep

Table 1
Summary of maternal covid status, weeks postpartum at assessment, demographic and psychosocial information.

	N = 232
COVID status (positive)	89 (38.4%)
Weeks postpartum at time of assessment	18.4 ± 1.9
Gestational age at birth	38.7 ± 1.7
Mode of delivery (vaginal)	146 (62.9%)
Infant sex (female)	104 (44.8%)
Feeding	
Exclusively/mostly breastfeeding	111 (47.8%)
Equally breastfeeding and formula feeding	42 (18.1%)
Exclusively/mostly formula feeding	79 (34.0%)
Maternal age	32.1 ± 5.3
Insurance (commercial)	134 (57.7%)
Race/ethnicity	
White non-Hispanic	62 (26.7%)
African American	17 (7.3%)
Hispanic	107 (46.1%)
Other	46 (19.8%)
Sleeping arrangement	
Separate rooms	40 (17.2%)
Room sharing in separate crib	176 (75.8%)
Bedsharing	13 (7.3%)
Infant sleep perceived as a problem	
No	161 (69.4%)
Moderate/severe	70 (30.2%)
PSS	18.3 ± 5.3
PHQ-9	2.4 ± 7.8
PCL5	7.2 ± 7.0

PSS, Perceived Stress Scale; PHQ9, Patient Health Questionnaire 9; PCL5, Post-traumatic Stress Disorder Checklist for DSM-5.
Values provide as mean (standard deviation) or number (percentage).

Table 2
Summary of maternal report of sleep health at 4 monhts postpartum via the PSQI questionnaire.

	N = 232
Subjective sleep quality	
Very good	46 (19.8%)
Fairly good	131 (56.4%)
Fairly bad	45 (19.4%)
Very bad	10 (4.3%)
Sleep latency	
≤15 min	78 (33.9%)
16-30 min	89 (38.7%)
31-60 min	45 (19.5%)
>60 min	18 (7.8%)
Sleep duration	
>7	57 (25.2%)
6-7	44 (19.4%)
5-6	98 (43.3%)
<5	27 (11.9%)
Sleep efficiency	
>85%	95 (40.9%)
75%-84%	45 (19.4%)
65%-74%	39 (16.8%)
<65%	55 (23.7%)
Sleep disturbances	
PSQI 5 score = 0	53 (23.0%)
PSQI 5 score = 1	162 (70.4%)
PSQI 5 score = 2	12 (5.2%)
Sleep medications	
Not during the past month	212 (91.8%)
Less than once a week	9 (3.8%)
Once or twice a week	2 (0.8%)
Three or more times week	8 (3.4%)
Daytime dysfunction	0.4 ± 0.5
PSQI 7 score = 0	141 (60.8%)
PSQI 7 score = 1	86 (37.1%)
PSQI 7 score = 2	4 (1.7%)

PSQI, Pittsburgh Sleep Quality Index.

efficiency lower than the recommended clinical threshold of 85%. Additional metrics from the PSQI questionnaire are found in Table 2.

Tables 3a and 3b report all the statistics for the analyses reported in the following sections.

Subjective sleep quality

The results of the univariate analyses for subjective sleep quality showed that the following variables had p values $\leq .2$ and were thus included in the multivariate model: COVID-19 status, infant sex, time of the pandemic at delivery, being from Hispanic or Other race/ethnicity, maternal age at delivery, insurance, PSS score, PHQ-9 score, PCL5 score, bedsharing, and considering infant sleep to be a problem (Supplementary Table S1). Results from the multivariable regression indicated that mothers' subjective sleep quality was worse for those who delivered in May-June compared to those who delivered in March-April ($\beta = 1.3 \pm 0.5$, $p = .02$). In addition, higher scores on the PSS, PHQ-9, PCL5 and perception of the infant's sleep as a problem were associated with worse maternal subjective sleep quality ($\beta = 0.08 \pm 0.02$, $p < .001$; $\beta = 0.3 \pm 0.06$, $p < .001$; $\beta = 0.06 \pm 0.02$, $p = .001$; $\beta = 1.0 \pm 0.3$, $p = .002$, respectively).

Sleep latency

The results of the univariate analyses for sleep latency showed that the following variables had p values $\leq .2$ and were thus included in the multivariate model: delivery mode, time of the pandemic at delivery, being African American, Hispanic or from Other races/ethnicities, insurance, PSS, PHQ-9, PCL5 and bedsharing (Supplementary

Table 3a
Results from multivariate ordinal models of each sleep domain and predictors with a $p \leq 0.2$ in the univariate analyses. See supplementary material for results of univariate analyses.

	PSQ1		PSQ2		PSQI3		PSQI4		PSQI5		PSQI7		PSQI tot	
	$\beta \pm$ SE	p val	$\beta \pm$ SE	p val	$\beta \pm$ SE	p val	$\beta \pm$ SE	p val	$\beta \pm$ SE	p val	$\beta \pm$ SE	p val	$\beta \pm$ SE	p val
COVID-19 status														
Negative	Ref													
Positive	−0.4 ± 0.3	0.1												
Gestational Age at delivery									−0.06 ± 0.09	0.5	0.005 ± 0.1	0.9	−0.1 ± 0.1	0.2
Infant sex	0.4 ± 0.3	0.1			0.4 ± 0.2	0.08	0.2 ± 0.2	0.4						
Delivery Mode														
Vaginal			Ref								Ref			
Cesarean			0.4 ± 0.3	0.1							−0.1 ± 0.3	0.7		
Feeding														
Exclusively/mostly breastfeeding	Ref													
Equally breastfeeding and formula feeding	−0.3 ± 0.4	0.4												
Exclusively/mostly formula feeding	0.008 ± 0.3	0.9												
Time of pandemic at delivery														
March-April	Ref		Ref						Ref				Ref	
May-June	1.3 ± ± 0.5	0.02	1.3 ± 0.6	0.02					1.6 ± 0.6	0.009			1.1 ± 0.6	0.07
July-August	0.9 ± 0.5	0.08	1.3 ± 0.5	0.01					1.4 ± 0.6	0.01			1.1 ± 0.6	0.05
September-October	0.9 ± 0.5	0.08	1.0 ± 0.5	0.05			0.7 ± 0.4	0.1	1.3 ± 0.6	0.02			1.3 ± 0.6	0.02
November-December	0.5 ± 0.6	0.4	1.1 ± 0.6	0.05					1.5 ± 0.6	0.02			0.6 ± 0.6	0.4

Table 3b
Results from multivariate ordinal models of each sleep domain and predictors with a $p \leq 0.2$ in the univariate analyses. See supplementary material for results of univariate analyses.

	PSQ1		PSQ2		PSQ3		PSQ4		PSQ5		PSQ7		PSQ tot	
	$\beta \pm$ SE		*p* val		$\beta \pm$ SE		*p* val		$\beta \pm$ SE		*p* val		$\beta \pm$ SE	
Race														
White non-Hispanic	Ref		Ref		Ref		Ref		Ref		Ref		Ref	
African American	0.5 ± 0.6	0.3	1.0 ± 0.5	0.06	0.6 ± 0.5	0.3	0.6 ± 0.5	0.3					1.0 ± 0.7	0.1
Hispanic	−0.3 ± 0.4	0.4	0.9 ± 0.3	0.01	0.7 ± 0.3	0.04	0.7 ± 0.3	0.04	−0.8 ± 0.4	0.06	-1.7 ± 0.5	<0.001	0.9 ± 0.4	0.02
Other	0.2 ± 0.4	0.8	1.3 ± 0.4	<0.001	0.7 ± 0.4	0.05	0.7 ± 0.4	0.05	−0.5 ± 0.5	0.2			0.7 ± 0.4	0.1
Maternal age	0.01 ± 0.03	0.6							−0.009 ± 0.03	0.8				
Insurance														
Commercial	Ref		Ref		Ref		Ref		Ref		Ref			
Medicaid	−0.5 ± 0.3	0.2	0.3 ± 0.3	0.2	0.6 ± 0.3	0.05	0.6 ± 0.3	0.05	0.3 ± 0.4	0.4	0.7 ± 0.4	0.06		
PSS	0.08 ± 0.02	<0.001	0.07 ± 0.02	<0.001					0.07 ± 0.02	0.002	0.1 ± 0.02	<0.001	0.07 ± 0.02	0.001
PHQ-9	0.3 ± 0.06	<0.001	0.2 ± 0.05	<0.001					0.3 ± 0.07	<0.001	0.5 ± 0.07	<0.001	0.2 ± 0.07	<0.001
PCL5	0.06 ± 0.02	0.001	0.06 ± 0.02	<0.001					0.1 ± 0.02	<0.001	0.1 ± 0.02	<0.001	0.08 ± 0.03	0.002
Sleep arrangement														
Separate rooms	Ref		Ref		Ref		Ref		Ref		Ref		Ref	
Share room														
Bedsharing	0.9 ± 0.6	0.1	1.0 ± 0.6	0.1	0.8 ± 0.6	0.2	0.8 ± 0.6	0.2	1.3 ± 0.8	0.1	1.1 ± 0.8	0.2	2.4 ± 1.1	0.04
Infant sleep as a problem														
No	Ref				Ref		Ref		Ref		Ref			
Moderate/severe	1.0 ± 0.3	0.002			0.9 ± 0.3	0.001	0.9 ± 0.3	0.001	0.7 ± 0.4	0.07	0.5 ± 0.4	0.2	0.8 ± 0.3	0.02

PSS, Perceived Stress Scale; PHQ9, Patient Health Questionnaire 9; PCL5, Post-traumatic Stress Disorder Checklist for DSM-5; PSQI, Pittsburgh Sleep Quality Index.

Table S2). The multivariable regression indicated that mothers' sleep latency was longer for those who delivered in May-June, July-August, September-October, and November-December compared to those who delivered in March-April (β = 1.3 ± 0.6, p = .02; β = 1.3 ± 0.5, p = .01; β = 1.0 ± 0.5, p = .05; β = 1.1 ± 0.6, p = .05, respectively). In addition, mothers who self-identified as Hispanic and from Other races/ethnicities had longer sleep latency compared to non-Hispanic White mothers (β = 0.9 ± 0.3, p = .01; β = 1.3 ± 0.4, p < .001, respectively). Lastly, mothers with higher scores on the PSS, PHQ-9 and PCL5 had longer sleep latency (β = 0.07 ± 0.02, p < .001; β = 0.2 ± 0.05, p < .001; β = 0.06 ± 0.02, p < .001, respectively).

Sleep duration

The results of the univariate analyses for sleep duration showed that the following variables had p values ≤ .2 and were thus included in the multivariate model: infant sex, being Hispanic or from Other races/ethnicities, maternal age, PSS, PHQ-9, PCL5, bedsharing and perception of infant's sleep as a problem (Supplementary Table S3). Results from the multivariable regression indicated that mothers' sleep duration was significantly shorter for women who self-identified as Hispanic or from Other races/ethnicities compared to non-Hispanic White mothers (β = 0.7 ± 0.3, p = .04; β = 0.7 ± 0.4, p = .05, respectively). Lastly, mothers with higher scores on the PSS and PHQ9 and who perceived their infants' sleep as a severe/moderate problem has a shorter sleep duration (β = 0.04 ± 0.02, p = .03; β = 0.1 ± 0.05, p = .01; β = 0.7 ± 0.3, p = .02, respectively).

Sleep efficiency

The results of the univariate analyses for sleep efficiency showed that the following variables had p values ≤ .2 and were thus included in the multivariate model: infant sex, having delivered between September-October, being African American, Hispanic or from Other races/ethnicities, insurance status, PSS, PHQ-9, PCL5, bedsharing and perception of infant's sleep as a problem (Supplementary Table S4). Results from the multivariable regression indicated that mothers' sleep efficiency was worse if they were Hispanic or from Other race/ethnicities compared to White non-Hispanic (β = 0.7 ± 0.3, p = .04; β = 0.7 ± 0.4, p = .05, respectively), if they had Medicaid/public health insurance compared to a commercial health insurance (β = 0.6 ± 0.3, p = .05) and if they perceived their infants' sleep as a severe/moderate problem (β = 0.9 ± 0.3, p = .001).

Sleep disturbances

The results of the univariate analyses for sleep disturbances showed that the following variables had p values ≤ .2 and were thus included in the multivariate model: gestational age at delivery, time of the pandemic at delivery, being Hispanic or from Other races/ethnicities, maternal age, insurance status, PSS, PHQ-9, PCL5, bedsharing and perception of infant's sleep as a problem (Supplementary Table S5). Results from the multivariable regression indicated that mothers' sleep disturbances were worse if they had delivered in May-June, July-August, September-October, and November-December compared to March-April (β = 1.6 ± 0.6, p = .009; β = 1.4 ± 0.6, p = .01; β = 1.3 ± 0.6, p = .02; β = 1.5 ± 0.6, p = .02). In addition, mothers with higher PSS, PHQ-9 and PCL5 scores had more sleep disturbances (β = 0.07 ± 0.02, p = .002; β = 0.3 ± 0.07, p < .001; β = 0.1 ± 0.02, p < .001, respectively).

Sleep medications

Only 19 out of 232 mothers (8.2%) reported taking sleep medications. Thus, for power reasons, we did not run statistical analyses for this sleep domain.

Daytime dysfunction

The results of the univariate analyses for daytime dysfunction showed that the following variables had p values $\leq .2$ and were thus included in the multivariable model: gestational age at delivery, being Hispanic, insurance status, PSS, PHQ-9, PCL5, bedsharing and perception of the infant's sleep as a problem (Supplementary Table S6). Results from the multivariate regression indicated that Hispanic women experienced less daytime dysfunction compared to non-Hispanic White women ($\beta = -1.7 \pm 0.5$, $p < .001$). In addition, mothers with higher PSS, PHQ-9 and PCL5 scores ($\beta = 0.1 \pm 0.02$, $p < .001$; $\beta = 0.5 \pm 0.07$, $p < .001$; $\beta = 0.1 \pm 0.02$, $p < .001$, respectively) experienced more daytime dysfunction.

Global PSQI score

The results of the univariate analyses for the global PSQI score showed that the following variables had p values $\leq .2$ and were thus included in the multivariate model: gestational age at delivery, time of the pandemic at delivery, being African American, Hispanic or from Other races/ethnicities, PSS, PHQ-9, PCL5, bedsharing and perception of the infant's sleep as a problem (Supplementary Table S7). Results from the multivariable regression indicated that mothers who delivered in July-August and September-October were more likely to have poor overall sleep quality (scores above 5) compared to those who delivered in March-April ($\beta = 1.1 \pm 0.06$, $p = .05$; $\beta = 0.3 \pm 0.06$, $p = .02$, respectively). Hispanic women were more likely to have poor overall sleep quality (scores above 5) compared to non-Hispanic White women ($\beta = 0.9 \pm 0.4$, $p = .02$). In addition, mothers with higher PSS, PHQ-9 and PCL5 scores, who practiced bed sharing and did not perceive infant's sleep as a problem were more likely to have a global PSQI score above 5 ($\beta = 0.07 \pm 0.02$, $p = .001$; $\beta = 0.2 \pm 0.07$, $p < .001$; $\beta = 0.08 \pm 0.003$, $p = .02$; $\beta = 2.4 \pm 1.1$, $p = .04$; $\beta = 0.08 \pm 0.03$, $p = .02$, respectively).

In Supplementary Table S8, results can be found for the analysis with the global score of the PSQI treated as a continuous variable.

Discussion

In this study, we report on maternal sleep health in the postpartum period during the unique period of the COVID-19 pandemic in NYC. Our findings indicate that maternal COVID-19 infection during pregnancy did not significantly influence maternal sleep postpartum in any domain. However, women who delivered after the first peak of the pandemic in NYC (May-December 2020) reported worse global PSQI scores, sleep latency and disturbances than those who delivered during the first peak in NYC (March-April 2020). These differences remained significant even when we accounted for psychosocial factors.

Although we did not have a prepandemic cohort to compare our results to, a few papers in the literature have reported on maternal sleep at 3-4 months postpartum. Studies utilizing sleep logs and actigraphy have reported that mothers at this timepoint sleep on average 6.5-7 hours (6.4 hours ± 0.5 in Horiuchi et al,[6] 6.75 hours ± 1.14 in Cottrell et al[29] 7.2 ± 0.95 in Montgomery-Downs et al[5]). In our sample, ~55% of mothers reported sleeping less than 6 hours. We could not find studies reporting on other sleep domains in the same time window, since many of the studies in the literature regarding postpartum sleep have focused on earlier timepoints.[30,31]

While we are not aware of any other previous study on postpartum sleep during the COVID-19 pandemic,[32] results from studies in the general population are inconsistent. A few studies have focused on sleep during the peak of the pandemic: results from a study performed in Canada from April to June 2020 showed that the emergence of new sleep difficulties during the pandemic was independently associated with female sex, chronic illnesses, being employed, family responsibilities, earlier wake-up times, higher stress levels, as well as heavier alcohol use and television exposure.[19] Another study that examined data from an international sample from March to May 2020 found that during lock-down periods sleep duration was longer and there was less difference in sleep schedules between workdays and days off.[17] Similarly, another international study from metropolitan areas, found that in NYC sleep duration increased 25 minutes on average comparing March-April 2019 with March-April 2020.[18] Another study analyzed a nationally representative sample of US adults, comparing sleep metrics from 2018 to 2020. They found that while average sleep duration did not change between 2018 and 2020, the prevalence of both shorter and longer than recommended sleep duration was greater in 2020. Moreover, the number of days with difficulty falling asleep, difficulty staying asleep, and not feeling rested was greater in 2020 than 2018, with major differences in adults younger than 60.[20] These studies highlight the heterogeneity of the effects of the pandemic on sleep health. In addition, they show one limitation of the literature on sleep during the COVID-19 pandemic, which either focused on sleep at the peak of the pandemic or lumped together sleep metrics from several months of the pandemic.[20] Thus, our study adds significantly to the literature, being the first to report on postpartum women and taking into account time of the pandemic. Our results may be specific to the pandemic context in NYC where the pandemic was characterized by a sharp peak in infection rates in March-April 2020 followed by a steady improvement until a smaller but more prolonged second peak beginning in November-December 2020. One potential factor driving our results are the changes due to return to work in-person that started during Fall 2020, or the effect of prolonged/chronic exposure to "COVID-fatigue" more than the acute effects.[33]

Another significant contribution of our study is the evidence of racial/ethnic differences in maternal sleep postpartum, with Hispanic mothers experiencing worse sleep health. Previous studies on racial/ethnic disparities in sleep in the postpartum period are scarce. A study by Christian et al looked at the effect of race and parity on sleep quality and found no effect of race postpartum.[34] In that study, assessment occurred earlier than our study (4-12 weeks postpartum) and Hispanic/Latina women were excluded. Another study estimated normative values for postpartum sleep in a sample of majority White (93%) and married (91%) mothers from high SES and indicated that sleep duration during the first 4 months postpartum was relatively stable at approximately 7.2 hours per night, and a sleep efficiency of 80% at 2 weeks postpartum increasing to 90% at 4 months.[5] A similar study performed with a sample of African American and Hispanic/Latina women from low SES backgrounds reported shorter duration of sleep (6.5 hours per night) and lower sleep efficiency of 74% at 6 weeks postpartum and 78% at 5 months.[35] A recent study reported on determinants of postpartum sleep in minority women (African American and Hispanic), but did not have a White non-Hispanic group as comparison. They found bedsharing to be significantly associated with poorer sleep efficiency, which was not replicated in our study. Nonetheless the percentage of women practicing bedsharing in our sample was lower compared to their sample (7.3% and 11.5%, respectively). Interestingly, in our sample only 7.7% mothers practicing bedsharing were non-Hispanic White, while the rest identified as African American, Hispanic or Other race/ethnicity. Although mothers from racial/ethnic minorities experience poorer sleep across multiple domains (duration, latency, efficiency), Hispanic mothers were

less likely to report daytime dysfunction. A possible interpretation of these findings comes from the knowledge that people from race/ethnic minority groups are more likely to experience poor sleep but less likely to report it. For instance, a study performing a secondary analysis of the National Health and Nutrition Examination Survey 2005-2010[36] found that although racial/ethnic minority women had poorer sleep health, they were less likely to report trouble sleeping to a physician compared to White women. The observed racial/ethnic differences in sleep are likely to be associated with several factors, that may include individual, family, home, neighborhood, cultural, and societal factors, as described by the social ecological model.[37-39] In our multivariable models, we accounted for SES, maternal psychosocial functioning and information on bedsharing as potential factors contributing to maternal racial/ethnic disparities. We found that SES was a significant predictor of sleep efficiency and maternal mental health variables were associated with almost all sleep domains, but Hispanic women experienced worse sleep even after accounting for these measures. Thus, our results extend knowledge from studies of the general population which indicate that adults from racial/ethnic minority communities in the United States are at increased risk for poor sleep health,[23] filling a gap in the literature regarding racial/ethnic disparities in sleep during the postpartum period. These results are even more significant taken in the context of the pandemic, during which racially/ethnically minoritized communities have carried a heavier burden, both due to higher infection rates and experiences of social and financial stressors.

Another significant finding in our study is the relationship between maternal perception of the infant's sleep and maternal sleep quality, duration and efficiency. This is in line with previous literature. A similar study in Israel on 5-8 months old infants also found that maternal report of infant sleep difficulties was associated with maternal sleep difficulties. Most of the literature on the relationship between infant and maternal sleep has focused on the influence of maternal depression,[40,41] so here we provide evidence of the robust parallels between maternal and infant sleep while accounting for maternal depression and stress. We believe that this finding could have implications for clinical care, since it suggests that maternal report of infant sleep problems at infant's checkup could prompt a suggestion/invitation to mothers to check in about their own sleep health with a health care provider. This is particularly relevant since new mothers are routinely required to do a checkup appointment 6 weeks after delivery and if a mother is healthy and there are no concerns, the next appointment is at 1 year after delivery, with the risk of missing a critical window for identification of poor sleep. The importance of maternal sleep health in the postnatal period is often underappreciated and identification of strategies to identify mothers suffering from poor sleep health is of paramount importance.

Maternal psychological distress, as captured by measures of perceived stress, depression and COVID-19 related post-traumatic stress, was significantly associated with several domains. Depression, stress and COVID-19 related post-traumatic stress were significant predictors of poorer sleep quality, longer latency, more disturbances and daytime dysfunction and higher global PSQI scores. Depressive symptoms and stress were also associated with shorter sleep duration. Similar relationships between mental health and sleep during the COVID-19 pandemic have been described in pregnant women,[42,43] but no studies so far reported on postpartum women.

Limitations of this study include the sparse information about sleep environment and routines (eg, TV in the room, bedtime routines), sociodemographic factors (eg, education, marital status), and the absence of objective sleep measures.[44] Another limitation is the small sample of African American mothers in the cohort. Importantly, we also did not evaluate the unique contribution of differential exposure to structural or individual-level factors associated with race such as structural racism or discrimination on maternal sleep health.

In summary, this is the first study describing sleep health in the postpartum period during the COVID-19 pandemic. We found that mothers who delivered after the first COVID-19 peak in NYC (March-April 2020) experienced worse sleep compared to mothers who delivered during the pandemic peak. In addition, we observed marked racial/ethnic disparities, such that Hispanic mothers experienced worse sleep health compared to non-Hispanic White mothers. Maternal mental health and perception of infant sleep as a problem were also significant determinants of maternal sleep. Given the short-term and long-term implications of poor maternal sleep health for maternal physical and mental health and relationship with infant health, these results underscore the importance of sleep education and support for postpartum mothers, particularly during challenging times. In addition, our results document racial/ethnic disparities in global PSQI scores, sleep latency, sleep duration and efficiency, and thus highlight the need to further investigate root causes and mechanisms contributing to these inequities. This knowledge will be crucial in guiding decisions on where to invest resources and how to develop strategies to improve sleep in the postpartum period and account for the needs of populations experiencing health inequities.

Declaration of conflict of interest

DD has pending consultation fees from Medela, Inc. The other authors have declared no conflicts of interest.

Acknowledgments

Eunice Kennedy Shriver National Institute of Child Health and Human Development under grant number P2CHD058486, awarded to the Columbia Population Research Center. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. The authors thank the participants of this study for their generous contribution to this work at the time of high uncertainty and stress. The authors also thank the entire COMBO team for their commitment to rapid generation of critical knowledge of the pandemic's effects on mothers and infants (www.ps.columbia.edu/COMBO).

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.sleh.2021.10.009.

References

1. Hunter LP, Rychnovsky JD, Yount SM. A selective review of maternal sleep characteristics in the postpartum period. *J Obstet Gynecol Neonatal Nurs*. 2009;38(1):60–68.
2. Christian LM, Carroll JE, Teti DM, Hall MH. Maternal sleep in pregnancy and postpartum part I: mental, physical, and interpersonal consequences. *Curr Psychiatry Rep*. 2019;21(3):1–8.
3. Doering JJ. The physical and social environment of sleep in socioeconomically disadvantaged postpartum women. *J Obstet Gynecol Neonatal Nurs*. 2013;42(1):E33–E43.
4. Sivertsen B, Harvey AG, Reichborn-Kjennerud T, Torgersen L, Ystrom E, Hysing M. Later emotional and behavioral problems associated with sleep problems in toddlers: a longitudinal study. *JAMA Pediatr*. 2015;169(6):575–582.
5. Montgomery-Downs HE, Insana SP, Clegg-Kraynok MM, Mancini LM. Normative longitudinal maternal sleep: the first 4 postpartum months. *Am J Obstet Gynecol*. 2010;203(5):465. https://doi.org/10.1016/j.ajog.2010.06.057. .e1-7.
6. Horiuchi S, Nishihara K. Analyses of mothers' sleep logs in postpartum periods. *Psychiatry Clin Neurosci*. 1999;53(2):137–139.
7. Swain AM, O'Hara MW, Starr KR, Gorman LL. A prospective study of sleep, mood, and cognitive function in postpartum and nonpostpartum women. *Obstet Gynecol*. 1997;90(3):381–386. https://doi.org/10.1016/S0029-7844(97)89252-6.
8. Xiao RS, Kroll-Desrosiers AR, Goldberg RJ, Pagoto SL, Person SD, Waring ME. The impact of sleep, stress, and depression on postpartum weight retention: a systematic review. *J Psychosom Res*. 2014;77(5):351–358. https://doi.org/10.1016/j.jpsychores.2014.09.016.

9. Tikotzky L, Sadeh A, Volkovich E, Manber R, Meiri G, Shahar VII G. Infant sleep development from 3 to 6 months postpartum: links with maternal sleep and paternal involvement. *Monogr Soc Res Child Dev*. 2015;80(1):107–124.
10. Zambrano DN, Mindell JA, Reyes NR, Hart CN, Herring SJ. "It's not all about my baby's sleep": a qualitative study of factors influencing low-income African American mothers' sleep quality. *Behav Sleep Med*. 2016;14(5):489–500. https://doi.org/10.1080/15402002.2015.1028063.
11 Altena E, Baglioni C, Espie CA, et al. Dealing with sleep problems during home confinement due to the COVID-19 outbreak: practical recommendations from a task force of the European CBT-I Academy. *J Sleep Res*. 2020;29(4):e13052. Published online.
12. Morin CM, Carrier J, Bastien C, Godbout R, Network O behalf of the CS and C. Sleep and circadian rhythm in response to the COVID-19 pandemic. *Can J Public Health*. 2020;111(5):654–657. https://doi.org/10.17269/s41997-020-00382-7.
13. Park CL, Russell BS, Fendrich M, Finkelstein-Fox L, Hutchison M, Becker J. Americans' COVID-19 stress, coping, and adherence to CDC guidelines. *J Gen Intern Med*. 2020;35(8):2296–2303. https://doi.org/10.1007/s11606-020-05898-9.
14. Stanton R, To QG, Khalesi S, et al. Depression, anxiety and stress during COVID-19: associations with changes in physical activity, sleep, tobacco and alcohol use in Australian adults. *Int J Environ Res Public Health*. 2020;17(11):4065.
15. Kantermann T. Behavior: how a global social lockdown unlocks time for sleep. *Curr Biol*. 2020;30(14):R822–R823. https://doi.org/10.1016/j.cub.2020.06.037.
16. Wright KP, Linton SK, Withrow D, et al. Sleep in university students prior to and during COVID-19 stay-at-home orders. *Curr Biol*. 2020;30(14):R797–R798. https://doi.org/10.1016/j.cub.2020.06.022.
17. Roitblat Y, Burger J, Leit A, et al. Stay-at-home circumstances do not produce sleep disorders: an international survey during the COVID-19 pandemic. *J Psychosom Res*. 2020;139: 110282. https://doi.org/10.1016/j.jpsychores.2020.110282.
18. Robbins R, Affouf M, Weaver MD, et al. Estimated sleep duration before and during the COVID-19 pandemic in major metropolitan areas on different continents: observational study of smartphone app data. *J Med Internet Res*. 2021;23(2):e20546. https://doi.org/10.2196/20546.
19. Robillard R, Dion K, Pennestri M-H, et al. Profiles of sleep changes during the COVID-19 pandemic: demographic, behavioural and psychological factors. *J Sleep Res*. 2021;30(1):e13231. https://doi.org/10.1111/jsr.13231.
20. Hisler GC, Twenge JM. Sleep characteristics of US adults before and during the COVID-19 pandemic. *Soc Sci Med*. 2021;276: 113849.
21. Kirby T. Evidence mounts on the disproportionate effect of COVID-19 on ethnic minorities. *Lancet Respir Med*. 2020;8(6):547–548.
22. Hale L, Troxel WM, Kravitz HM, Hall MH, Matthews KA. Acculturation and sleep among a multiethnic sample of women: the Study of Women's Health Across the Nation (SWAN). *Sleep*. 2014;37(2):309–317.
23. Johnson DA, Jackson CL, Williams NJ, Alcántara C. Are sleep patterns influenced by race/ethnicity—a marker of relative advantage or disadvantage? Evidence to date. *Nat Sci Sleep*. 2019;11:79–95. https://doi.org/10.2147/NSS.S169312.
24 Jackson CL, Johnson DA. Sleep disparities in the era of the COVID-19 pandemic highlight the urgent need to address social determinants of health like the virus of racism. *J Clin Sleep Med*. 2021;16(8):1401–1402. https://doi.org/10.5664/jcsm.8570.
25. Buysse DJ, Reynolds III CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res*. 1989;28(2):193–213.
26. Hita-Contreras F, Martínez-López E, Latorre-Román PA, Garrido F, Santos MA, Martínez-Amat A. Reliability and validity of the Spanish version of the Pittsburgh Sleep Quality Index (PSQI) in patients with fibromyalgia. *Rheumatol Int*. 2014;34(7):929–936.
27. Maroufizadeh S, Omani-Samani R, Almasi-Hashiani A, Amini P, Sepidarkish M. The reliability and validity of the Patient Health Questionnaire-9 (PHQ-9) and PHQ-2 in patients with infertility. *Reprod Health*. 2019;16(1):137. https://doi.org/10.1186/s12978-019-0802-x.
28 Andreou E, Alexopoulos EC, Lionis C, et al. Perceived stress scale: reliability and validity study in Greece. *Int J Environ Res Public Heal*. 2011;8(8):3287–3298. https://doi.org/10.3390/ijerph8083287.
29. Cottrell L, Karraker KH. Correlates of nap taking in mothers of young infants. *J Sleep Res*. 2002;11(3):209–212. https://doi.org/10.1046/j.1365-2869.2002.00305.x.
30. Lee KA. Alterations in sleep during pregnancy and postpartum: a review of 30 years of research. *Sleep Med Rev*. 1998;2(4):231–242.
31. Rychnovsky J, Hunter LP. The relationship between sleep characteristics and fatigue in healthy postpartum women. *Women's Heal Issues*. 2009;19(1):38–44.
32. Jahrami H, BaHammam AS, Bragazzi NL, Saif Z, Faris M, Vitiello M V. Sleep problems during the COVID-19 pandemic by population: a systematic review and meta-analysis. *J Clin sleep Med JCSM*. 2021;17(2):299–313. https://doi.org/10.5664/jcsm.8930.
33. Queen D, Harding K. Societal pandemic burnout: a COVID legacy. *Int Wound J*. 2020;17(4):873–874. https://doi.org/10.1111/iwj.13441.
34. Christian LM, Carroll JE, Porter K, Hall MH. Sleep quality across pregnancy and postpartum: effects of parity and race. *Sleep Health*. 2019;5(4):327–334. https://doi.org/10.1016/J.SLEH.2019.03.005.
35. Herring SJ, Yu D, Spaeth A, et al. Influence of sleep duration on postpartum weight change in black and Hispanic women. *Obesity (Silver Spring)*. 2019;27(2):295–303. https://doi.org/10.1002/oby.22364.
36. Amyx M, Xiong X, Xie Y, Buekens P. Racial/ethnic differences in sleep disorders and reporting of trouble sleeping among women of childbearing age in the United States. *Matern Child Health J*. 2017;21(2):306–314. https://doi.org/10.1007/s10995-016-2115-9.
37. Bronfenbrenner U. *The Ecology of Human Development: Experiments by Nature and Design*. Harvard University Press; 1979.
38. Buysse DJ. Sleep health: can we define it? Does it matter? *Sleep*. 2014;37(1):9–17. https://doi.org/10.5665/sleep.3298.
39. Grandner MA, Williams NJ, Knutson KL, Roberts D. Sleep disparity, race /ethnicity, and socioeconomic position. *Sleep Med*. 2020;18(2016):7–18. https://doi.org/10.1016/j.sleep.2015.01.020.
40. Dennis C-L, Ross L. Relationships among infant sleep patterns, maternal fatigue, and development of depressive symptomatology. *Birth*. 2005;32(3):187–193. https://doi.org/10.1111/j.0730-7659.2005.00368.x.
41. Hairston IS, Solnik-Menilo T, Deviri D, Handelzalts JE. Maternal depressed mood moderates the impact of infant sleep on mother-infant bonding. *Arch Womens Ment Health*. 2016;19(6):1029–1039. https://doi.org/10.1007/s00737-016-0652-2.
42. Lin W, Wu B, Chen B, et al. Sleep conditions associate with anxiety and depression symptoms among pregnant women during the epidemic of COVID-19 in Shenzhen. *J Affect Disord*. 2021;281:567–573. https://doi.org/10.1016/j.jad.2020.11.114.
43. Khoury JE, Atkinson L, Bennett T, Jack SM, Gonzalez A. COVID-19 and mental health during pregnancy: the importance of cognitive appraisal and social support. *J Affect Disord*. 2021;282:1161–1169. https://doi.org/10.1016/j.jad.2021.01.027.
44. Rudzik AEF, Robinson-Smith L, Ball HL. Discrepancies in maternal reports of infant sleep vs. actigraphy by mode of feeding. *Sleep Med*. 2018;49:90–98. https://doi.org/10.1016/j.sleep.2018.06.010.