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Sleep and mental health in pregnancy during COVID-19: A parallel process growth model

Lianne Tomfohr Madsen[1,2,3]

Charlie Rioux[4]

Anna MacKinnon[1,2]

Katherine Silang[1]

Leslie Roos[4]

Catherine Lebel [2, 5]

Gerald F. Giesbrecht [1,2,3]

Corresponding Author: Lianne Tomfohr Madsen, ltomfohr@ucalgary.ca

1. Department of Psychology, University of Calgary, Calgary, AB
2. Alberta Children's Hospital Research Institute (ACHRI), Calgary, AB
3. Department of Pediatrics, University of Calgary, Calgary, AB
4. Department of Psychology, University of Manitoba, Winnipeg, MB
5. Department of Radiology, University of Calgary, Calgary, AB

Abstract

Pregnancy is associated with elevated risk for poor sleep quality, which increases the risk for poor obstetrical outcomes and parent mental health problems. The COVID-19 pandemic has seen increased reports of disturbed sleep worldwide; however, the degree this extends to pregnancy or influences pregnancy mental health outcomes has not been examined. The goal of this study was to examine changes in pregnant individuals' sleep, anxiety and depression during the pandemic, and to understand how sleep was associated with symptoms of anxiety and depression over time. The Pregnancy During the COVID-19 Pandemic (PdP) study is a prospective longitudinal cohort of pregnant individuals (at enrollment) with repeated follow ups during pregnancy and the postpartum period. 3747 pregnant individuals participated between April and July 2020. The present analysis was restricted to participants who completed at least two assessments, yielding a final sample of 1842 pregnant individuals. Depression symptoms were elevated at baseline, and declined gradually over time, but remained elevated relative to pre pandemic levels. Shorter sleep duration, higher sleep disturbance, and more sleep related impairments at baseline predicted a slower decline in depression symptoms over time. More sleep disturbances at baseline also predicted slower decline in anxiety symptoms over time. In contrast, rates of depression and anxiety symptoms at baseline were not predictive of changes in any of the three sleep variables over time. These findings highlight the importance of early intervention for sleep problems in pregnancy, in order to optimize mental health throughout pregnancy and mitigate long term negative outcomes.

Keywords

Pregnancy; sleep; anxiety; depression; COVID 19; pandemic; longitudinal

Sleep problems, including symptoms of insomnia and poor sleep quality, are common in pregnancy, and tend to increase as pregnancy progresses.[1,2] Sleep problems in pregnancy are associated with poor obstetrical outcomes, including increased risk of preterm birth.[3] Poor sleep quality and short sleep duration have also been shown to predict declines in mental health over time, with sleep problems being more predictive of later depression than vice versa in pregnant and non-pregnant populations.[4,5] The direction of the relationship between sleep and anxiety during pregnancy is less clear, with some evidence that experiencing anxiety in early pregnancy is predictive of later symptoms of insomnia[6] and decreasing sleep duration.[7] Exposure to mental health problems during the perinatal period can negatively impact child developmental outcomes and family relationships, thus identifying potential modifiable risk factors is an important priority.[8]

Since being declared a worldwide pandemic, COVID-19 and the restrictions implemented to limit its spread have impacted every area of daily functioning including work changes, cancelled school/daycare, relationship strain, and social isolation. Prior to the COVID-19 pandemic, rates of perinatal depression and anxiety were approximately 12-15%.[9,10] Rapid reviews and meta analyses suggest significantly elevated rates of mental health problems across populations, including in pregnancy.[11] Additionally, rates of poor sleep quality increased, with higher elevations observed in women (compared to men).[12] Disturbed sleep and lower sleep quality in pregnant individuals also appear to be more common during the pandemic compared to pre pandemic levels.[13] However, the research conducted on sleep in pregnancy during COVID-19 has been crosssectional in nature and it is unclear how sleep changed as the pandemic progressed, or whether poor sleep was a risk factor for worse mental health symptoms across the perinatal period. Studies have found that, at the population level, rates of depression and anxiety

were elevated at the onset of the pandemic, and decreased during the first wave.[14] It is unclear whether that is also the case at the intraindividual level and in pregnant individuals. While sleep problems in pregnancy were found to be associated with increases in depression and anxiety before the pandemic, it is unclear how they associate in a historic situation where anxiety and depression levels are both abnormally elevated and decreasing. Even beyond the pandemic, it is important to better understand the temporal nature of the relationship between sleep and mental health in pregnancy in order to prioritize intervention development and delivery.

Objectives

The present study aimed to: (1) examine changes in sleep duration, sleep disturbance, sleep related impairments, and symptoms of anxiety and depression in pregnant individuals during the first wave of the COVID 19 pandemic in Canada (i.e., April to July 2020); and (2) examine how levels and change in sleep and mental health variables relate to each other over time.

Methods

Study protocol and procedures

The current investigation utilized data from the larger Pregnancy During the COVID-19 Pandemic (PdP) study,[15] a prospective longitudinal cohort of pregnant individuals (at enrollment) with repeated follow ups during pregnancy and the postpartum period. Ethics approval was obtained from the Conjoint Health Research Ethics Board (CHREB) at the University of Calgary (REB20 0500), and all participants provided informed consent. Recruitment and data collection began in April 2020. Participants were eligible if they were: pregnant, ≥17 years old, ≤35 weeks gestation at study enrollment, living in Canada, and able to read and write in English or French. At enrollment, participants completed an initial online survey that gathered information on

demographic and socioeconomic characteristics, and included several validated self-report questionnaires that assessed physical and mental health such as sleep, anxiety, and depression. For three months following the initial assessment, participants received a monthly email link to complete follow up surveys about experiences since the previous survey. This investigation followed the methods outlined by the standards set by STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines (cite; see supplementary materials for checklist).[16]

Sample

A total of 3747 individuals with a delivery due date after July 31, 2020 provided exclusively antepartum data between April and July 2020. The sample for the current investigation was restricted to those with data from at least two timepoints of four month monthly assessments between April and July 2020, in order to have adequate covariance coverage to conduct longitudinal analyses, yielding a final sample of 1842 participants. There were differences between individuals with data at ≥ two timepoints compared to those with data only at the one timepoint: participants were more likely to complete ≥2 questionnaires by July 2020 if they had a higher income (OR = 1.13, 95% CI: 1.09, 1.16, $p < .001$), higher education (OR = 1.61, 95% CI: 1.07, 2.42, $p < .001$), and were in a marriage or domestic partnership (OR = 1.61, 95% CI: 1.07, 2.42, $p = .022$); there were no differences in terms of previous miscarriages or depression and anxiety disorder diagnoses before pregnancy ($p > .50$). Furthermore, analyses examining attrition according to mental health at study onset (April ($n = 1234$)) showed that the odds of completing two or more timepoints were lower for those with higher levels of depression (OR = 0.95, 95% CI: 0.93, 0.97, $p <.001$) and anxiety in April (OR = 0.97, 95% CI: 0.96, 0.99, $p = .009$).

The average age of participants in April was 32.78 years (*SD* = 4.05, range = 19 to 49 years). The median yearly household income of participants was $100,000 124,999 CDN. 86.1% of participants were born in Canada. 84.5% of participants identified as White, 0.7% as First Nations, 1.0% as Metis, 0.1% as Inuit, 0.9% as Black, 2.2% as Chinese, 1.4% as Filipino, 0.2% as Korean, 0.3% as West Asian, 2.4% as South Asian, 0.5% as Southeast Asian, 1.7% as Hispanic/Latinx, and 3.9% as Mixed Race or Other. 78.3% of participants were married and 19.8% were in a domestic partnership, with the remaining being single (1.7%), divorced (0.1%) or separated (0.2%). 18.2% of participants had completed a trade or community college diploma, 43.4% completed a Bachelor's degree, and 32.1% had a graduate or professional degree.

Measures

Sleep related variables. Sleep duration was self-reported at each assessment with a single item from the Pittsburgh Sleep Quality Index[17] asking participants "During the PAST MONTH, how many hours of actual sleep did you get a night? (This may be different than the number of hours you spend in bed)". Skewness for sleep duration ranged from 0.05 to 0.14 across the four assessments, and kurtosis = 0.07 to 0.22.

Sleep disturbance and sleep related impairment were self-reported at each assessment using the four item Patient Reported Outcomes Measurement Information System (PROMIS®) Sleep Disturbance – Short Form 4a and the four item PROMIS® Sleep Related Impairment Short Form 4a.[18] Items are answered on a 5 point scale and summed scores can range from 4 to 20, where higher scores indicate more severe symptoms. Scores of 16 to 19 on the sleep disturbance scale and 12 to 15 on sleep related impairment are indicative of moderate problems and scores of 20 on sleep disturbance and ≥16 on sleep related impairments are considered severely elevated. In the current investigation, sleep disturbance had a skewness range of 0.25 to

0.34, kurtosis of 0.42 to 0.49, and Cronbach's alpha (α) of 0.81 to 0.85 across time points, whereas sleep related impairment had a skewness range of 0.50 to 0.57, kurtosis of 0.41 to 0.59, and α = 0.89 to 0.92.

Anxiety and depression symptoms. General anxiety symptoms were self-reported at each assessment using the PROMIS® Anxiety Adult 7 item short form.[19] Items are answered on a 5-point scale and summed scores can range from 7 to 35, where higher scores indicate more severe symptoms. Scores of 20 to 27 are indicative of moderately elevated anxiety symptoms and scores ≥28 are indicative of severely elevated anxiety symptoms. Skewness ranged from 0.01 to 0.32, kurtosis from 0.57 to 0.81, and all α = 0.94.

Depression symptoms were self-reported at each assessment using the 10 item Edinburgh Postpartum Depression Scale,[20] which is validated for assessments conducted during pregnancy.[21] Items are answered on a 4 point scale and summed scores can range from 0 to 30, where higher scores indicate more severe symptoms. A cut off score of ≥13 is used to identify individuals with clinically concerning depression symptoms.[20] Skewness ranged from 0.37 to 0.58, kurtosis from 0.13 to 0.01, and α = 0.88 to 0.89.

Covariates. Potential confounding variables were accounted for in the analyses as covariates, and included baseline report of: education level (high school degree or lower vs. post-secondary education), household income, changes in household income due to COVID-19, marital status (married or in a domestic partnership vs. single, divorced, widowed or separated), number of previous births, having had a miscarriage prior to the current pregnancy, and number of weeks until delivery due date on April 1, 2020.

Data analyses

Latent growth models (LGMs) were constructed in Mplus 8.5[22] using maximum likelihood estimation. Analyses were conducted in two steps. First, unconditional LGMs were estimated separately for sleep duration, sleep disturbance, sleep related impairments, anxiety, and depression. These univariate models estimate two latent growth parameters: (1) an intercept, which was centered in April as an estimate of the initial levels; and (2) a linear slope, which captures change over time. Second, parallel (i.e., bivariate) LGMs were conducted to examine the associations between the sleep, anxiety, and depression growth factors. Six bivariate LGMs were estimated, including sleep duration, sleep disturbance, and sleep related impairments each with anxiety and depression. Figure 1 shows the associations tested in these models. The models estimate: autoregressive paths for the mental health variable intercepts predicting mental health variable slopes (a) and for sleep variable intercepts predicting sleep variable slopes (b); correlations between sleep and mental health variable intercepts (c) and between sleep and mental health variable slopes (d); and regression paths for mental health variable intercepts predicting sleep variable slopes (e) and sleep variable intercepts predicting mental health variables' slopes (f). All covariates (see measures section) were included in the bivariate LGMs by regressing the intercepts and slopes on these variables. The Benjamini–Hochberg procedure[23] was used to correct for multiple testing.

Tests of goodness of model fit included the model chi square (χ^2), the Comparative Fit Index (CFI) the Tucker Lewis Index (TLI), the Root Mean Square Error of Approximation (RMSEA), and the Standardized Root Mean Residual (SRMR). An adequate fit is suggested by a non-significant χ^2, a CFI and TLI > 0.90 and a RMSEA and SRMR < 0.08, and close fit is suggested by a CFI and TLI > 0.95 and a RMSEA and SRMR < 0.05.[24]

Full information maximum likelihood (FIML) was used to account for missing data under the missing completely at random (MCAR) and missing at random (MAR) assumptions.[25] Missing data analyses showed that of the 1842 participants, 358 had data at all four timepoints. 1163 enrolled in May or June and therefore had missing data for previous assessments, which was considered MCAR,[25] but had complete data thereafter. 321 withdrew or missed assessments after joining the study. Missing data rates for each variable are provided in supplementary materials. Household income, number of children, previous miscarriages, marital status, education, anxiety and depression diagnoses before pregnancy, temporary or permanent job loss due to COVID-19, and income change due to COVID-19 were examined as potential predictors of withdrawal and missed assessments (i.e., potential predictors of MAR[25] within the analyzed sample). All were found to be nonsignificant predictors of missingness ($p > .10$) and were thus not included as auxiliary variables (variables that are not in the analytical model but are included for missing data estimation). Anxiety and depression at study onset were related to attrition (see sample section). As these variables were already in the models, this was taken into account in FIML estimation under the MAR assumption.

Results

Descriptive statistics

Descriptive statistics of the study variables are presented in Table 1. Cross tabulations conducted in SPSS showed that in April, participants with moderately to severely elevated sleep disturbance had higher rates of severely elevated anxiety symptoms compared to participants with lower sleep disturbance levels (82% vs. 47%; $\chi^2(1) = 37.93$, $p < .001$). The same was found for participants with moderate to severe sleep related impairments (72% vs. 40%; $\chi^2(1) = 73.72$, $p < .001$). Similarly, participants with moderately to severely elevated sleep disturbance and

sleep related impairments had higher rates of clinically concerning depression symptoms compared to participants with lower sleep disturbance and impairment (disturbance 68% vs. 26%; $\chi^2(1) = 63.55$, $p < .001$; impairments 54% vs. 19%; $\chi^2(1) = 107.00$, $p < .001$). Correlations between all sleep and mental health variables across the four assessments can be found in Supplementary Materials.

Univariate growth models

Table 2 shows model fit indices and parameter estimates for the univariate LGMs. For all models, the chi square test was significant. However, this test is sensitive to sample size, and with a large sample size such as in the present study, large power leads the chi square test to be significant.[24] All other model fit indices showed acceptable to close fit.

On average, initial sleep duration was 7 hours 17 minutes and significantly decreased by 10 minutes per month. Sleep disturbance had a significantly increasing slope. While the slope mean of sleep related impairments was non-significant, the slope variance was significant. Accordingly, while on average there was no significant change across participants, there was significant within participant variance where some had increasing and some had decreasing sleep related impairments. Results (see Table 2) showed that both anxiety and depression symptoms had a significant decreasing slope between April and July. All intercept and slope parameters had significant variance.

Bivariate growth models

As can be seen in Table 3, all bivariate LGMs had adequate model fit. Results of the bivariate LGMs are presented in Table 4. Initial levels of sleep duration and anxiety symptoms were negatively associated and initial levels of sleep related impairments and anxiety symptoms were positively associated, but there were no longitudinal associations between these two sleep

related variables and anxiety (i.e., intercepts did not predict slopes in either direction). Initial levels of sleep disturbance and anxiety symptoms were positively associated and higher initial levels of sleep disturbance predicted a slower decline in anxiety symptoms, whereas anxiety symptoms did not predict the slope of sleep disturbance.

Associations between initial levels of the sleep variables and symptoms of depression were similar to those found for anxiety, but there was stronger evidence of longitudinal associations. Initial sleep duration and levels of depression symptomatology were negatively associated, and lower initial sleep duration predicted a slower decline in symptoms of depression. Initial levels of sleep disturbance and symptoms of depression were positively associated, and slopes of sleep disturbance and symptoms of depression were positively associated, indicating that a steeper increase in sleep disturbance was associated with a slower decline in depression symptomatology. Higher initial levels of sleep disturbance also predicted a slower decline in depression symptomatology. Similarly, higher initial levels of sleep related impairments and symptoms of depression and were positively associated, and a steeper increase in sleep related impairments was associated with a slower decline in depression symptoms. Higher initial levels of sleep related impairments also predicted a slower decline in depression symptoms. In contrast, initial levels of depression symptoms did not predict the three sleep related slopes.

Discussion

Here, we provide important insight into links between pregnant individuals' sleep problems and mental health difficulties in a large longitudinal sample during the COVID-19 pandemic. Shorter sleep duration, more disturbances, and sleep related impairment, were associated with higher symptoms of anxiety and depression among pregnant individuals during

the first wave of the COVID-19 pandemic. Consistent with other studies of non-pregnancy cohorts, from April to July 2020, rates of anxiety and depression decreased within the overall sample,[14] although they remained higher when compared to pre-pandemic levels.[11] Over the course of the study, sleep disturbance increased and sleep duration declined – a pattern in line with the broader pregnancy literature.[1,2,6] Shorter sleep duration, higher sleep disturbance and more sleep related impairments at baseline predicted a slower decline in depression symptoms. Increasing sleep related impairment and disturbances over time were also associated with a slower decline in symptoms of depression. In contrast, initial depression symptoms were not predictive of changes in sleep. At baseline, shorter sleep duration, more sleep replated impairments and disturbance were associated with higher anxiety. Whereas there were no longitudinal associations between sleep duration and sleep related impairments with anxiety, higher sleep disturbance at baseline was predictive of a slower decrease in anxiety over the course of the study. Similar to depression, initial rates of anxiety did not predict the slope of any of the sleep variables. While previous studies in children, adolescents and adults have found that sleep is predictive of later mental health problems[26,27]; these findings suggests that poor sleep quality was also associated with slower recovery from high rates of anxiety and depression during early phases of the pandemic and that sleep may be a key target for intervention.

Sleep problems in pregnancy are common and given their serious long-term impact when left untreated, they should be considered part of standard perinatal mental health screening protocols. Pregnant individuals show a strong preference for psychotherapy (i.e., cognitive behavioural therapy for insomnia (CBT I)) versus pharmacotherapy for the treatment of insomnia.[28] Recent studies suggest that both in person and online CBT-I delivered in pregnancy significantly reduce symptoms of insomnia.[29-32] Data from our research group also shows that

CBT I reduced symptoms of insomnia during the COVID-19 pandemic when delivered via telehealth.[33] Treating insomnia in pregnancy also appears to reduce symptoms of depression, with evidence showing benefit up to two years postpartum.[30,32] Data from this study, and others longitudinal cohorts add to a burgeoning literature showing the impact of untreated sleep problems on later symptoms of depression, and point to an urgent need for accessible treatment options to be disseminated.[4,5,34]

Treating sleep problems in pregnancy may also be an important prevention-based strategy for promoting child health and development. Poor sleep quality in pregnancy has been shown to predict shorter infant sleep duration and longer wake after sleep onset.[35] Poor sleep in infancy and early childhood has itself been linked to important child health and developmental outcomes.[36-39] Additionally, perinatal depression is associated with risk for many negative child outcomes.[40] When maternal depression persists into the postpartum period or beyond, further impacts are seen on child development at both biological (i.e. altered brain development) and behavioral (i.e. delays in socioemotional and cognitive development) levels.[41,42] Such negative impacts of maternal depression are exacerbated in the presence of postpartum sleep difficulties and other stressors, such as domestic conflict or poverty related stress, given the high demands of caring for infants while managing high burdens of internal distress alongside inadequate psychosocial support.

Strengths and Limitations

The current investigation utilized data from a large national prospective pregnancy cohort study conducted during the COVID-19 pandemic. While this provides an unprecedented opportunity to examine the sleep and mental health of pregnant individuals within the context of adversity, the results should be interpreted with limitations in mind. Although there were no

significant differences in previous anxiety or depression diagnoses among participants who were excluded from the study for withdrawing after the initial assessment, similar to other pandemic studies, later attrition was higher among those with elevated symptoms of anxiety and depression at baseline.[43] This may have contributed to the lack of significant findings for anxiety and depression predicting later sleep problems; it may also suggest that the strength of association between sleep and mental helath was underestimated. Furthermore, all data were self-reported, raising the possibility of shared method variance accounting for a portion of the associations.[44] The PROMIS sleep tools are commonly used measures of sleep quality; however, although informative, self-report measures of sleep are poorly correlated with objective measurements.[45] The sample was also highly educated and had high household income, and while sociodemographic factors were accounted for in the analyses, the results may not be generalizable to specific subpopulations with more vulnerabilities such as job or food insecurity, lack of access to health care, adequate housing, transportation and language barriers. The experience of pregnancy, labor and delivery may have differed depending on the phase of the pandemic, and these differences are not addressed in our analyses. Finally, other important variables known to influence both mental health and sleep, such as social isolation or illness (e.g., COVID infection) may have influenced our results.

Conclusions

The current findings suggest that poor sleep during pregnancy leads to more persistent symptoms of anxiety and depression across the perinatal period during chronic stressful events such as the COVID-19 pandemic. Poor sleep in pregnancy is highly responsive to treatment and broader screening and treatment may improve parental mental health outcomes.

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Declaration of Conflicts of Interest

The authors have no conflicts of interest to declare.

References

1. Sedov I, Cameron EE, Madigan S, Tomfohr-Madsen LM. Sleep quality during pregnancy: A meta-analysis. *Sleep Medicine Reviews*. 2017;38:168-176. doi:https://doi.org/10.1016/j.smrv.2017.06.005

2. Sedov ID, Anderson NJ, Dhillon AK, Tomfohr-Madsen LM. Insomnia symptoms during pregnancy: A meta-analysis. *J Sleep Res*. Feb 2021;30(1):e13207. doi:10.1111/jsr.13207

3. Yang Z, Zhu Z, Wang C, Zhang F, Zeng H. Association between adverse perinatal outcomes and sleep disturbances during pregnancy: a systematic review and meta-analysis. *The Journal of Maternal-Fetal & Neonatal Medicine*. 2022;35(1):166-174. doi:10.1080/14767058.2020.1711727

4. González-Mesa E, Cuenca-Marín C, Suarez-Arana M, et al. Poor sleep quality is associated with perinatal depression. A systematic review of last decade scientific literature and meta-analysis. *Journal of perinatal medicine*. 2019;47(7):689-703. doi:0.1515/jpm-2019-0214

5. Zhai L, Zhang H, Zhang D. Sleep Duration and Depression among Adults: A Meta-Analysis of Prospective Studies. *Depress Anxiety*. Sep 2015;32(9):664-70. doi:10.1002/da.22386

6. Sedov ID, Tomfohr-Madsen LM. Trajectories of Insomnia Symptoms and Associations with Mood and Anxiety from Early Pregnancy to the Postpartum. *Behavioral Sleep Medicine*. 2020:1-12.

7. van der Zwan JE, de Vente W, Tolvanen M, et al. Longitudinal associations between sleep and anxiety during pregnancy, and the moderating effect of resilience, using parallel process latent growth curve models. *Sleep Medicine*. 2017;40:63-68.

8. Pires GN, Benedetto L, Cortese R, et al. Effects of sleep modulation during pregnancy in the mother and offspring: Evidences from preclinical research. *Journal of Sleep Research*. 2020:e13135.

9. Dennis CL, Falah-Hassani K, Shiri R. Prevalence of antenatal and postnatal anxiety: systematic review and meta-analysis. *Br J Psychiatry*. May 2017;210(5):315-323. doi:10.1192/bjp.bp.116.187179

10. Woody CA, J. FA, J. SD, A. WH, G. HM. A systematic review and meta-regression of the prevalence and incidence of perinatal depression. *Journal of Affective Disorders*. 2017;219(May):86--92. doi:10.1016/j.jad.2017.05.003

11. Tomfohr-Madsen LM, Racine N, Giesbrecht GF, Lebel C, Madigan S. Depression and anxiety in pregnancy during COVID-19: A rapid review and meta-analysis. *Psychiatry Research*. 2021;doi:https://doi.org/10.1016/j.psychres.2021.113912

12. Yuksel D, McKee GB, Perrin PB, et al. Sleeping when the world locks down: Correlates of sleep health during the COVID-19 pandemic across 59 countries. *Sleep Health*. 2021;7(2):134-142. doi:10.1016/j.sleh.2020.12.008

13. Demissie DB, Bitew ZW. Mental health effect of COVID-19 pandemic among women who are pregnant and/or lactating: A systematic review and meta-analysis. *SAGE Open Medicine*. 2021;9:205031212110261. doi:10.1177/20503121211026195

14. Daly M, Robinson E. Psychological distress and adaptation to the COVID-19 crisis in the United States. *Journal of Psychiatric Research*. 2021;136:603-609. doi:https://doi.org/10.1016/j.jpsychires.2020.10.035

15. Giesbrecht GF, Bagshawe M, Van Sloten M, et al. Protocol for the Pregnancy During the COVID-19 Pandemic (PdP) Study: A Longitudinal Cohort Study of Mental Health Among

Pregnant Canadians During the COVID-19 Pandemic and Developmental Outcomes in Their Children *JMIR Res Protoc*. 2021;10(4):e25407. doi:10.2196/25407

16. Cuschieri S. The STROBE guidelines. *Saudi J Anaesth*. Apr 2019;13(Suppl 1):S31-S34. doi:10.4103/sja.SJA_543_18

17. Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. Article. *Psychiatry Res*. May 1989;28(2):193-213. doi:10.1016/0165-1781(89)90047-4

18. Yu L, Buysse DJ, Germain A, et al. Development of Short Forms From the PROMIS (TM) Sleep Disturbance and Sleep-Related Impairment Item Banks. Article. *Behav Sleep Med*. 2012;10(1):6-24. doi:10.1080/15402002.2012.636266

19. Pilkonis PA, Choi SW, Reise SP, et al. Item Banks for Measuring Emotional Distress From the Patient-Reported Outcomes Measurement Information System (PROMIS (R)): Depression, Anxiety, and Anger. Article. *Assessment*. Sep 2011;18(3):263-283. doi:10.1177/1073191111411667

20. Cox JL, Holden JM, Sagovsky R. Detection of Postnatal Depression: Development of the 10-item Edinburgh Postnatal Depression Scale. Article. *Br J Psychiatry*. Jun 1987;150:782-786. doi:10.1192/bjp.150.6.782

21. Bergink V, Kooistra L, Lambregtse-van den Berg MP, et al. Validation of the Edinburgh Depression Scale during pregnancy. Article. *J Psychosomat Res*. Apr 2011;70(4):385-389. doi:10.1016/j.jpsychores.2010.07.008

22. Muthén LK, Muthén BO. *Mplus User's Guide*. 8th ed. Muthén & Muthén; 1998-2017.

23. Thissen D, Steinberg L, Kuang D. Quick and easy implementation of the Benjamini-Hochberg procedure for controlling the false positive rate in multiple comparisons. Article. *J Educ Behav Stat*. Spr 2002;27(1):77-83. doi:10.3102/10769986027001077

24. Little TD. *Longitudinal Structural Equation Modeling*. Methodology in the Social Sciences. The Guildford Press; 2013:385.

25. Graham JW. Missing Data Analysis: Making It Work in the Real World. *Annual Review of Psychology*. 2009;60:549-576. doi:10.1146/annurev.psych.58.110405.085530

26. Marino C, Andrade B, Campisi SC, et al. Association Between Disturbed Sleep and Depression in Children and Youths. *JAMA Network Open*. 2021;4(3):e212373. doi:10.1001/jamanetworkopen.2021.2373

27. Li L, Wu C, Gan Y, Qu X, Lu Z. Insomnia and the risk of depression: a meta-analysis of prospective cohort studies. *BMC Psychiatry*. 2016;16(1)doi:10.1186/s12888-016-1075-3

28. Sedov I, Goodman SH, Tomfohr-Madsen LM. Insomnia treatment preferences among pregnant women. *JOGNN*. 2017;46(3):e95--e104. doi:doi: 10.1016/j.jogn.2017.01.005

29. Arnedt JT, Conroy DA, Mooney A, Furgal A, Sen A, Eisenberg D. Telemedicine versus face-to-face delivery of cognitive behavioral therapy for insomnia: a randomized controlled noninferiority trial. *Sleep*. 2021;44(1)doi:10.1093/sleep/zsaa136

30. Bei B, Pinnington DM, Quin N, et al. Improving perinatal sleep via a scalable cognitive behavioural intervention: findings from a randomised controlled trial from pregnancy to 2 years postpartum. *Psychological Medicine*. 2021:1-11. doi:10.1017/s0033291721001860

31. Silang KA, Sohal PR, Bright KS, et al. eHealth Interventions for Treatment and Prevention of Depression, Anxiety, and Insomnia During Pregnancy: Systematic Review and Meta-analysis. *JMIR Ment Health*. Feb 21 2022;9(2):e31116. doi:10.2196/31116

32. Manber R, Bei B, Simpson N, et al. Cognitive behavioral therapy for prenatal insomnia: a randomized controlled trial. *Obstetrics and Gynecology*. 2019;133(5):911-919. doi:10.1097/AOG.0000000000003216

33. MacKinnon AL, Guadagni V, Donnici C, et al. Sleep, emotions and mood disorders during the COVID 19 Pandemic across Countries and Populations. presented at: National Conference of the Canadian Sleep Society; October, 2021 2021; Virtual.

34. Baglioni C, Battagliese G, Feige B, et al. Insomnia as a predictor of depression: A meta-analytic evaluation of longitudinal epidemiological studies. *Journal of Affective Disorders*. 2011;135(1-3):10-19. doi:10.1016/j.jad.2011.01.011

35. Burdayron R, Pennestri MH, Keys EM, et al. Maternal Sleep Quality in Pregnancy and Infant Sleep: A Longitudinal Investigation. In review;

36. Wu Y, Gong Q, Zou Z, Li H, Zhang X. Short sleep duration and obesity among children: A systematic review and meta-analysis of prospective studies. *Obes Res Clin Pract*. Mar - Apr 2017;11(2):140-150. doi:10.1016/j.orcp.2016.05.005

37. Chaput JP, Gray CE, Poitras VJ, et al. Systematic review of the relationships between sleep duration and health indicators in school-aged children and youth. *Appl Physiol Nutr Metab*. Jun 2016;41(6 Suppl 3):S266-82. doi:10.1139/apnm-2015-0627

38. Matricciani L, Paquet C, Galland B, Short M, Olds T. Children's sleep and health: A meta-review. *Sleep Med Rev*. Aug 2019;46:136-150. doi:10.1016/j.smrv.2019.04.011

39. Short MA, Blunden S, Rigney G, et al. Cognition and objectively measured sleep duration in children: a systematic review and meta-analysis. *Sleep Health*. Jun 2018;4(3):292-300. doi:10.1016/j.sleh.2018.02.004

40. Stein A, Pearson RM, Goodman SH, et al. Effects of perinatal mental disorders on the fetus and child. *The Lancet*. 2014;384(9956):1800-1819.

41. Lebel C, Walton M, Letourneau N, Giesbrecht GF, Kaplan BJ, Dewey D. Prepartum and Postpartum Maternal Depressive Symptoms Are Related to Children's Brain Structure in Preschool. *Biological Psychiatry*. 2016;80(11):859-868. doi:10.1016/j.biopsych.2015.12.004

42. Slomian J, Honvo G, Emonts P, Reginster J-Y, Bruyère O. Consequences of maternal postpartum depression: A systematic review of maternal and infant outcomes. *Women's Health*. 2019;15:174550651984404. doi:10.1177/1745506519844044

43. Czeisler M, Wiley J, Czeisler C, Rajaratnam S, Howard M. Uncovering Survivorship Bias in Longitudinal Mental Health Surveys During the COVID-19 Pandemic. *Epidemiology and Psychiatric Sciences*. 2021;30:1-26. doi:10.1017/s204579602100038x

44. Grandner MA, Kripke DF, Yoon IY, Youngstedt SD. Criterion validity of the Pittsburgh Sleep Quality Index: Investigation in a non-clinical sample. *Sleep and Biological Rhythms*. 2006;4(2):129--136. doi:10.1111/j.1479-8425.2006.00207.x

45. Girschik J, Fritschi L, Heyworth J, Waters F. Validation of Self-Reported Sleep Against Actigraphy. *Journal of Epidemiology*. 2012;22(5):462-468. doi:10.2188/jea.je20120012

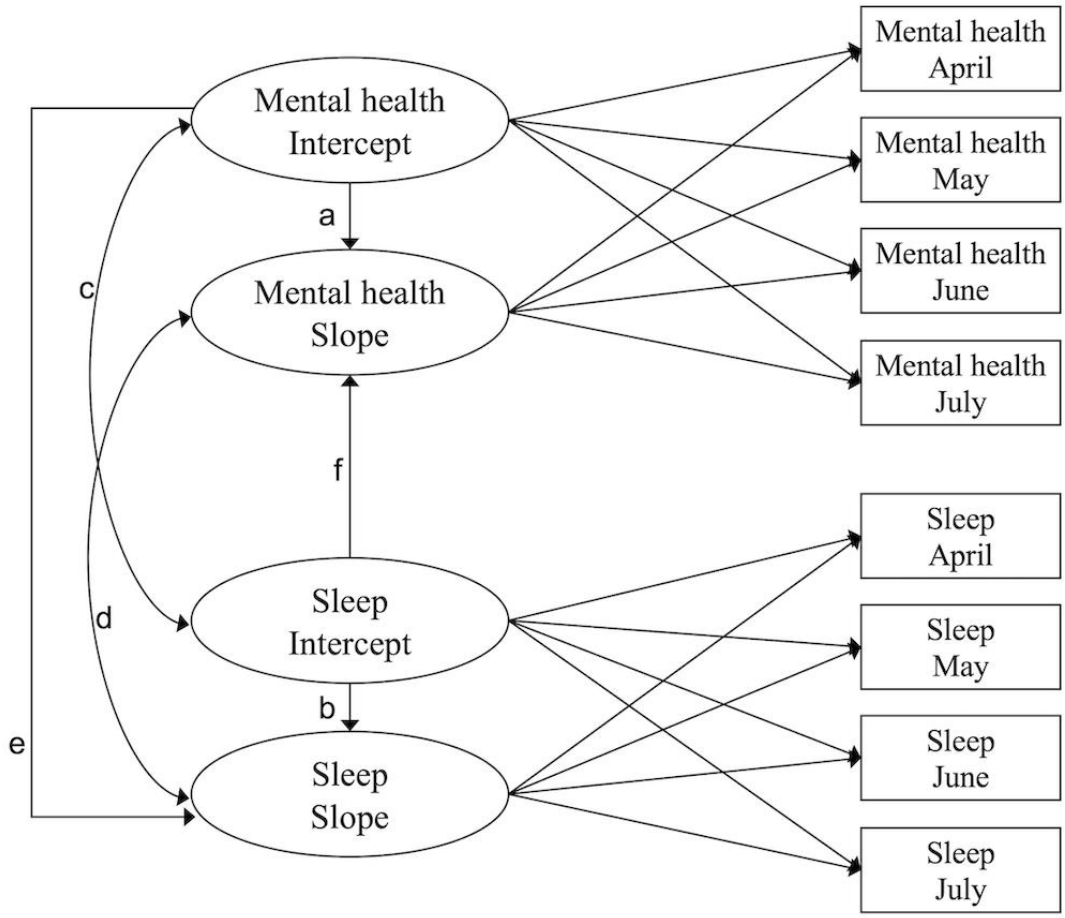

Fig. 1. Associations tested in the bivariate (parallel) latent growth models (LGMs). Mental health refers to depression or anxiety. Sleep refers to sleep duration, sleep disturbance, or sleep-related impairments.

Table 1. Descriptive statistics of study variables

	April (n = 825)		May (n = 1316)		June (n = 1520)		July (n = 1316)	
Variable	M (SD)	%	M (SD)	%	M (SD)	%	M (SD)	%
Anxiety symptoms	19.20 (6.12)		17.81 (6.02)		17.16 (5.95)		16.91 (5.99)	
Moderately elevated		42.3		35.1		31.6		30.6
Severely elevated		7.8		5.4		4.3		4.0
Depression symptoms	9.83 (5.20)		9.20 (5.21)		8.67 (5.32)		8.38 (5.35)	
Clinically concerning		30.1		26.4		23.1		21.6
Sleep duration	7.19 (1.17)		7.13 (1.26)		7.02 (1.22)		6.83 (1.29)	
Sleep disturbance	10.74 (3.38)		10.78 (3.55)		10.90 (3.53)		11.30 (3.53)	
Moderately elevated		9.8		10.8		11.3		12.3
Severely elevated		0.4		0.7		0.8		1.5
Sleep-related impairments	9.80 (3.72)		9.90 (3.97)		9.74 (3.88)		10.08 (4.01)	
Moderately elevated		23.9		22.8		21.8		24.0
Severely elevated		8.5		11.2		10.4		11.8

Note. M = Mean; SD = Standard Deviation.

Table 2. Model fit indices and parameters of univariate latent growth models for mental health and sleep-related variables

	Model fit					Parameter estimates				
	χ^2 (df=5)	CFI	TLI	RMSEA	SRMR	Intercept *M*	Intercept *v*	Slope *M*	Slope *v*	Intercept-Slope *r*
Anxiety symptoms	49.19***	.98	.98	.07	.04	19.11***	25.52***	-0.82***	0.94***	-0.18*
Depression symptoms	15.14**	.99	.99	.03	.02	10.12***	20.86***	-0.63***	0.90***	-0.26***
Sleep duration	17.02**	.99	.99	.04	.05	7.29***	1.09***	-0.16***	0.06***	-0.29***
Sleep disturbance	30.64***	.99	.99	.05	.05	10.79***	9.30***	0.13***	0.50***	-0.35***
Sleep-related impairments	27.77***	.99	.99	.05	.04	10.01***	10.54***	-0.03	0.58***	-0.27***

Note. CFI = Comparative Fit Index, TLI = Tucker-Lewis Index, RMSEA = Root-Mean-Square Error of Approximation, SRMR = Standardized Root-Mean Residual, *M* = mean, *v* = variance, *r* = correlation. *p<.05 **p<.001 ***p<.001

Table 3. Model fit indices of bivariate latent growth models between mental health and sleep-related variables

		Model fit				
Bivariate model between:		χ^2 (df=46)	CFI	TLI	RMSEA	SRMR
Anxiety	Sleep duration	114.00***	.99	.97	.03	.02
Anxiety	Sleep disturbance	109.05***	.99	.98	.03	.02
Anxiety	Sleep-related impairments	102.00***	.99	.98	.03	.02
Depression	Sleep duration	71.18*	.99	.99	.02	.02
Depression	Sleep disturbance	73.46**	.99	.99	.02	.02
Depression	Sleep-related impairments	64.24*	.99	.99	.02	.02

Note. CFI = Comparative Fit Index, TLI = Tucker-Lewis Index, RMSEA = Root-Mean-Square Error of Approximation, SRMR = Standardized Root-Mean Residual. *p<.05 **p<.001 ***p<.001

Table 4. Results of bivariate latent growth models between mental health and sleep-related variables

	Anxiety				**Depression**			
		95% CI				95% CI		
	Estimate(SE)	LL	UL	β/*r*	Estimate(SE)	LL	UL	β/*r*
Sleep duration								
a. mental health Intercept → Slope	-0.04(0.02)	-0.07	0.00	-0.19	-0.07(0.02)*	-0.10	-0.03	-0.31
b. sleep Intercept → Slope	-0.08(0.02)*	-0.25	0.07	-0.32	-0.08(0.02)*	-0.35	-0.07	-0.32
c. Intercept ↔ Intercept	-1.27(0.22)*	-1.70	-0.84	-0.26	-1.27(0.19)*	-1.64	-0.90	-0.29
d. Slope ↔ Slope	-0.04(0.03)	-0.10	0.03	-0.18	-0.02(0.03)	-0.07	0.04	-0.08
e. mental health Intercept → sleep Slope	0.00(0.01)	-0.01	0.00	-0.06	-0.01(0.00)	-0.01	0.00	-0.09
f. sleep Intercept → mental health Slope	-0.09(0.08)	-0.25	0.07	-0.10	-0.21(0.07)*	-0.35	-0.07	-0.23
Sleep disturbance								
a. mental health Intercept → Slope	-0.05(0.02)*	-0.09	-0.01	-0.26	-0.08(0.02)*	-0.12	-0.04	-0.40
b. sleep Intercept → Slope	-0.10(0.02)*	-0.14	-0.06	-0.45	-0.10(0.02)*	-0.15	-0.06	-0.44
c. Intercept ↔ Intercept	6.65(0.65)*	5.38	7.92	0.46	6.82(0.57)*	5.71	7.93	0.53
d. Slope ↔ Slope	0.14(0.09)	-0.03	0.32	0.25	0.14(0.07)	-0.01	0.28	0.25
e. mental health Intercept → sleep Slope	0.03(0.01)	0.01	0.05	0.22	0.03(0.01)	0.00	0.05	0.19
f. sleep Intercept → mental health Slope	0.07(0.03)*	0.00	0.13	0.21	0.09(0.03)*	0.04	0.15	0.30
Sleep-related impairment								
a. mental health Intercept → Slope	-0.05(0.02)	-0.10	-0.01	-0.28	-0.08(0.02)*	-0.13	-0.04	-0.41
b. sleep Intercept → Slope	-0.07(0.03)	-0.12	-0.01	-0.30	-0.07(0.03)	-0.13	-0.01	-0.29
c. Intercept ↔ Intercept	7.73(0.72)*	6.33	9.13	0.51	7.71(0.63)*	6.48	8.93	0.58
d. Slope ↔ Slope	0.25(0.11)	0.03	0.47	0.43	0.21(0.10)*	0.02	0.40	0.36
e. mental health Intercept → sleep Slope	0.03(0.02)	0.01	0.06	0.22	0.03(0.02)	0.00	0.07	0.20
f. sleep Intercept → mental health Slope	0.08(0.04)	0.01	0.15	0.26	0.09(0.03)*	0.03	0.15	0.30

Note. See Figure 1 for visualization of a-f paths. Estimate = unstandardized estimate; SE = standard error; CI = confidence interval; LL = lower limit; UL = upper limit; β = standardized beta for regression paths; *r* = correlation coefficient for correlation paths. Models control for education level), household income, changes in household income due to COVID-19, marital status, number of live children, having had a miscarriage prior to the current pregnancy, and number of weeks until delivery due date. *p<.05 after correction for multiple testing