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Prenatal maternal sleep and trajectories of postpartum depression and anxiety symptoms

Noa Gueron-Sela[1,2] | Golan Shahar[1] | Ella Volkovich[1] | Liat Tikotzky[1]

[1]The Department of Psychology, Ben-Gurion University of the Negev, Beer-Sheva, Israel

[2]Zlotowski Center for Neuroscience, Beer-Sheva, Israel

Correspondence
Noa Gueron-Sela, Department of Psychology, Ben-Gurion University of the Negev, P.O.B. 653, Beer-Sheva 8410501, Israel.
Email: gueron@post.bgu.ac.il

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Abstract

Postpartum emotional distress is very common, with 10%–20% of postpartum women reporting depressive or anxiety disorders. Sleep is a modifiable risk factor for emotional distress that has a pivotal role in postpartum adjustment. The present study aimed to examine whether sleep duration and quality during pregnancy predict trajectories of emotional distress in the postpartum period. Participants were 215 women that were assessed from the third trimester of pregnancy to 18-months postpartum. At all five time points (third trimester, 3-, 6-, 12-, and 18-months postpartum), measures of sleep duration and quality (measured by wake time after sleep onset; WASO) were derived from both actiography and diary-based measures. Repeated measures of depression and anxiety symptoms were collected using self-report measures. Results indicated four bivariate postpartum depression and anxiety growth trajectories, including (a) *high comorbidity* (5.4%); (b) *moderate comorbidity* (19.4%); (c) *low anxiety and decreasing depression symptomology* (18.6%); and (d) *low symptomology* (56.6%). Multinomial logistic regression analyses showed that mothers with shorter sleep durations during pregnancy were more likely to belong to the high comorbidity or moderate symptoms classes compared to the low symptomology class. In addition, mothers with higher WASO (i.e. lower sleep quality) at 3-months postpartum were more likely to belong to the moderate class compared to the low symptomology class. Given the potential negative implications of disrupted sleep in the perinatal period, the present study may inform future intervention studies that target sleep problems during pregnancy.

KEYWORDS

postpartum anxiety, postpartum depression, pregnancy, sleep

1 | INTRODUCTION

Sleep disturbances such as insufficient night-time sleep, frequent night-time awakenings and daytime sleepiness are highly prevalent during pregnancy (Mindell et al., 2015). Results from a recent meta-analysis indicated that 45.7% of expectant mothers experienced poor sleep quality, with increasing rates towards the third trimester (Sedov et al., 2018). Because sleep disturbances and symptoms of depression and anxiety are strongly intertwined (e.g. Asarnow & Manber, 2019), exploring the links between sleep and emotional distress in the perinatal period is gaining increased attention (Chang et al., 2010; Volkovich et al., 2016). Accumulating evidence suggests that subjective sleep disturbances, such as short sleep duration and low sleep quality during pregnancy, increases the risk for elevated postpartum depressive symptoms (Plancoulaine et al., 2017; Tomfohr et al., 2015). However, extant research is limited by the almost exclusive reliance on subjective self-reported sleep measures, and the focus on postpartum distress in isolated time points. Furthermore, whereas the links between subjective sleep and depressive symptoms have been

explored extensively, other aspects of postpartum emotional distress have been largely neglected. Hence, the present study aimed to extend previous research by assessing the links between objective and subjective measures of maternal sleep during pregnancy and trajectories of emotional distress from pregnancy to 18-months postpartum. We specifically focussed on symptoms of depression and anxiety due to their high prevalence and comorbidity in the postpartum period (Brassel, Townsend, Pickard, & Grenyer, 2019; Pawluski et al., 2017).

Symptoms of depression and anxiety are common in the postpartum period, with 10%–20% of postpartum women reporting anxiety or depressive disorders, and as many as 30% reporting subclinical (i.e. mild to moderate) levels of symptoms (Kingston et al., 2018; Pawluski et al., 2017). Depressive or anxiety symptomatology across the perinatal period also increases the risk of comorbidity, with research showing that the prevalence of comorbidity in the first year postpartum ranges between 2% and 13% (Falah-Hassani et al., 2017). Both clinical and subclinical postpartum depression and anxiety have been associated with a plethora of negative maternal and child outcomes (Field, 2010; Kingston et al., 2018; Stein et al., 2014), highlighting the need to identify modifiable risk factors that can be screened for and addressed as early as the prenatal period.

Sleep disturbances during pregnancy, such as insufficient night-time sleep, trouble falling asleep and frequent night-time awakenings have recently been identified as a prominent risk factor for perinatal postpartum depression and anxiety symptoms (Chang et al., 2010; Tomfohr et al., 2015). Although sleep disturbances are traditionally perceived as a symptom of mood disorders, sleep alterations often precede the onset of these disorders (Asarnow & Manber, 2019). Additionally, insomnia treatment during the third trimester of pregnancy has been associated with lower risk for postpartum depression symptoms in a randomised clinical trial (Khazaie et al., 2013), suggesting that sleep disturbances can trigger the development of postpartum depression.

1.1 | The present study

Although the links between sleep disturbances during pregnancy and postpartum emotional distress have been established (Plancoulaine et al., 2017; Tomfohr et al., 2015), previous research has been limited by subjective self-reported sleep measures, small and non-representative samples, cross-sectional designs, and an almost exclusive focus on postpartum depression (Chang et al., 2010). The present study aimed to address these gaps in several ways. First, we employed a five-time point longitudinal design to assess maternal emotional distress and sleep from pregnancy through to 18-months postpartum. Because recent research suggests that there is considerable heterogeneity in the course of depression and anxiety symptom through the perinatal period (Putnam et al., 2015), we used a trajectory-based approach to capture patterns of changes in depression and anxiety symptoms over time. Second, we used a multi-method approach to measure sleep, utilising both subjective and objective measures. Finally, to broaden the understanding of the links between sleep and postpartum distress, in addition to depression, we also assessed changes in anxiety symptoms and comorbid depression and anxiety.

To that end, the first aim of the present study was to identify trajectories of maternal depression and anxiety symptoms from 3- to 18-months postpartum, using bivariate growth mixture modelling methods. Our second and main aim was to examine whether measures of sleep duration and quality during pregnancy predict the odds of belonging to specific trajectory classes of depression and anxiety symptoms. In our measurement of sleep quality, we focussed on wake after sleep onset (WASO), a widely used measure of sleep quality during the pre- and postnatal periods that has been associated with symptoms of emotional distress (Park et al., 2013). We hypothesised that lower objective and subjective sleep duration and quality during pregnancy will predict higher odds of belonging to trajectory classes that typically display elevated levels of depression and anxiety symptoms.

2 | METHODS

2.1 | Participants

A total of 215 married couples expecting their first child were recruited during pregnancy through prenatal courses and announcements on internet forums for expectant parents. Two-parent families with a singleton, full-term pregnancy and a healthy infant were included in the study. Participant attrition rates through the five time points were: 7% (n = 16) at 3 months, 7% (n = 14) at 6 months, 12% (n = 23) at 12 months, and 15% (n = 25) at 18 months. The main reasons for discontinuation were lack of willingness to participate, overload, moving abroad, and medical problems. The families who withdrew from the study did not differ from participating families on sociodemographic variables (e.g. age and education of both parents). Given our focus on maternal sleep and emotional distress, the present study used only data provided by mothers.

2.2 | Procedure

The study protocol was reviewed and approved by the Helsinki Ethical Review Board at Soroka Medical Center, which is affiliated with Ben-Gurion University. The study included five home visits, starting from the third trimester of pregnancy (week 34–week 37), followed by four visits at 3-, 6-, 12-, and 18-months postpartum. At all five time points, mothers completed background and emotional distress questionnaires. In addition, mothers' sleep was assessed by actiography and a daily sleep-diary for 5 nights. After completing each assessment, participants received a graphic report of their sleep patterns, and a small gift.

2.3 | Measures

2.3.1 | Sleep assessment

Actiography

The actiograph is a watch-like device, which continuously registers body motility data that are translated to sleep–wake measures based on a computerised scoring algorithm. In the present study, we used the micro-motion logger sleep watch (Ambulatory Monitoring Inc.) with a 1-min epoch interval according to the standard working mode for sleep–wake scoring. Data were analysed based on Sadeh's validated scoring algorithm for adults (Sadeh et al., 1995). Mothers were asked to attach the actiograph to their non-dominant hand 15 min before they went to sleep, and remove it 15 min after morning wake-up time for 5 nights. Actiographic sleep measures were: (a) sleep duration, time in bed from sleep onset time to morning awakening, including nocturnal wakefulness; (b) WASO, minutes awake during the night. Both sleep duration and WASO were averaged across the monitoring period for all five time points.

Sleep diaries

Mothers completed a nightly report of their own sleep patterns in parallel to the actiographic assessment following each of the 5 assessment nights. The following sleep diary measures were included: (a) sleep duration, the interval between self-reported sleep onset time and morning awakening time, and (b) WASO, self-reported minutes awake during the night.

2.3.2 | Emotional distress assessment

Depressive symptoms

The Edinburgh Postnatal Depression Scale (EPDS) (Cox et al., 1987) is a widely used screening tool for postpartum depression and had been validated for use during pregnancy. It consists of 10 statements addressing maternal depressive symptoms during the past week. Higher scores indicate higher maternal depressive symptoms. In the present sample, Cronbach's α ranged from 0.77 to 0.80 for all assessment points.

Anxiety symptoms

The Beck Anxiety Inventory (BAI; Beck & Steer, 1993) is a well-validated questionnaire that consists of 21 questions asking about physiological (e.g. hand trembling) and cognitive (e.g. fear of losing control) aspects of anxiety with regards to the last week. All items are rated on a 4-point scale ranging from 0 to 3. Higher scores indicate higher anxiety symptoms. In the present study, Cronbach's α ranged from 0.74 to 0.84 for all assessment points.

2.3.3 | Covariates

Given the links between demographic factors and trajectories of postpartum emotional distress (e.g. McCall-Hosenfeld et al., 2016), we included a measure of socioeconomic status (i.e. number of rooms in the household) and maternal age as covariates. In addition, in order to elucidate the unique effect of sleep during pregnancy on class belonging, we included prenatal depression and anxiety symptoms as well as sleep duration and quality at 3-months postpartum as covariates in the regression models predicting class belonging.

2.4 | Statistical analyses

All statistical analyses were conducted using Mplus 7.31. First, in order to examine the general changes in depression and anxiety symptoms in the postpartum period, a bivariate (e.g. parallel process) growth model was conducted using depression and anxiety symptoms at 3-, 6-, 12- and 18-months postpartum. Time points were fixed to 0, 3, 9 and 15 to represent the number of months between each time point. Depression and anxiety symptoms at each time point were allowed to co-vary. Both linear and quadratic growth curves were tested. Overall model fit was determined using the root mean square error of approximation (RMSEA), standardised root mean square residual (SRMR), and Comparative Fit Index (CFI). Adequate fit was defined as CFI values ≥0.95, RMSEA values ≤0.06, and SRMR values ≤0.08 (Hu & Bentler, 1999).

In the next step, to identify distinct longitudinal classes of trajectories of depression and anxiety symptoms, a growth mixture modelling approach was utilised. Variances were constrained to be equal across classes in order to resolve convergence issues that occurred when unique variances across classes were estimated. Consistent with the recommendations suggested by Nylund-Gibson and Masyn (2016), and in line with the three-step approach to examining predictors and outcomes of latent class membership (Asparouhov & Muthén, 2014; Vermunt, 2010), the latent class enumeration was done without covariates in order to maintain the integrity and generalisability of the established latent class measurement model. Class solutions were examined for two through five classes and were compared using various fit indices. Entropy was evaluated to determine how accurate classifications were for each class solution; values close to 1.0 were considered to have adequate entropy (Wickrama et al., 2016). In addition, the Bayesian information criterion (BIC) and the Akaike information criterion (AIC) were used, with lower values indicating a better class solution. The bootstrapped likelihood ratio test (BLRT) and the Lo–Mendell–Rubin adjusted likelihood ratio test (LMR-LRT) were also used, with a value of $p < .05$ indicating a significant difference between the k and the k–1 class models (Nylund et al., 2007). Finally, overall interpretability was evaluated.

To examine the associations between the predictors and the latent classes, all covariates and predictors were entered simultaneously into multinomial logistic regression models. The regression models utilised the three-step classification (R3STEP) procedure in Mplus, that accounts for the modal assignment of an

TABLE 1 Means, *SD*s, and correlation matrix of study variables

	Time point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Sleep dur A	T1																				
2. Sleep dur A	T2	0.49***																			
3. WASO A	T1	−0.32***	−0.06																		
4. WASO A	T2	−0.10	0.02	0.20**																	
5. Sleep dur D	T1	0.57***	0.35***	−0.02	0.009																
6. Sleep dur D	T2	0.34***	0.67***	0.03	0.14	0.36***															
7. WASO D	T1	0.12	0.10	0.38***	0.03	−0.24***	0.05														
8. WASO D	T2	−0.04	0.04	0.06	0.61***	−0.07	−0.05	0.19**													
9. EPDS	T1	−0.06	−0.03	0.03	0.01	−0.08	0.03	0.10	0.04												
10. EPDS	T2	−0.05	−0.04	−0.01	−0.008	−0.10	−0.05	0.11	0.13	0.56***											
11. EPDS	T3	−0.25**	−0.10	0.07	0.001	−0.24**	−0.09	0.14	0.16*	0.40***	0.57***										
12. EPDS	T4	−0.13	−0.04	0.07	0.08	−0.24**	−0.02	0.15	0.15	0.43***	0.57***	0.62***									
13. EPDS	T5	−0.05	0.01	−0.05	0.10	−0.16	−0.004	0.25**	0.33***	0.40***	0.45***	0.52***	0.58***								
14. BAI	T1	−0.002	0.02	0.04	0.008	0.01	0.04	0.04	0.02	0.59***	0.38***	0.32***	0.43***	0.29**							
15. BAI	T2	−0.07	−0.007	0.08	0.050	−0.08	0.02	0.12	0.08	0.43***	0.65***	0.50***	0.55***	0.47***	0.46***						
16. BAI	T3	−0.17*	−0.03	0.01	0.015	−0.10	−0.07	0.02	0.14	0.32***	0.41***	0.64***	0.52***	0.46***	0.40***	0.61***					
17. BAI	T4	−0.14	−0.06	0.09	0.054	−0.21**	−0.11	0.11	0.13	0.30***	0.42***	0.51***	0.66***	0.45***	0.47***	0.55***	0.72***				
18. BAI	T5	−0.01	0.06	−0.004	−0.04	−0.05	0.08	0.12	0.09	0.36***	0.45***	0.46***	0.51***	0.61***	0.49***	0.61***	0.65***	0.67***			
19. Maternal age	T1	−0.02	0.06	0.07	0.05	0.008	−0.01	0.08	0.15*	0.07	0.10	0.15*	0.14	0.19*	0.05	0.06	0.07	0.09	−0.05		
20. Number of rooms	T1	0.15*	0.02	−0.10	−0.11	−0.08	0.05	−0.01	−0.11	−0.08	−0.06	−0.13	−0.14	−0.19*	0.01	−0.05	−0.05	−0.11	0.07	−0.04	
Mean		406.09	388.15	37.68	62.73	6.92	6.45	23.88	51.31	4.86	3.52	3.41	2.87	3.20	8.07	3.91	3.46	2.95	3.63	28.79	3.25
SD		51.77	55.23	31.15	31.11	0.87	0.95	25.04	36.59	3.78	3.19	3.41	3.16	3.51	6.89	4.40	3.82	3.66	4.61	3.28	0.91
N		209	185	209	185	213	187	212	188	215	191	178	155	135	214	192	178	154	134	214	213

Abbreviations: A, actiography measure; BAI, Beck Anxiety Inventory; D, diary measure; EPDS, Edinburgh Postnatal Depression Scale; *SD*, standard deviation; Sleep dur, sleep duration; T1, prenatal period; T2, 3-months postpartum; T3, 6-months postpartum; T4, 12-months postpartum; T5, 18-months postpartum; WASO, wake minutes after sleep onset.

*$p < .05$.

**$p < .01$.

***$p < .001$.

individual's posterior probability of inclusion in a given class, along with a correction for classification error (Asparouhov & Muthén, 2014; Vermunt, 2010).

2.5 | Missing data

The percentage of missing data ranged from 0% to 37% (see Table 1 for sample size for each of the study variables). The majority of missing data were due to attrition. Little's missing completely at random (MCAR) test was non-significant, $\chi^2 = 201.718$, $p = .700$, suggesting that data were missing completely at random. Thus, missing data were handled by the full information maximum likelihood procedure (FIML). Because FIML procedures allow for the use of all available data from each participant, the full sample of $n = 215$ was retained in all primary analyses.

3 | RESULTS

3.1 | Descriptive statistics

Means, standard deviations (*SD*s) and a correlation matrix of all study variables are presented in Table 1. Overall, 4.2% of the participants scored above the clinical cut-off (≥13; Cox et al., 1987) during pregnancy, and 1%–3% scored above the clinical cut-off in the postpartum time points. This pattern is consistent with previous studies using community samples of mothers in the perinatal period (Fredriksen et al., 2017). A similar pattern was evident for the mean BAI scores, with 10% of the participants scoring above the clinical cut-off (>16; Julian, 2011) during pregnancy, and 1.2%–4.2% scoring above the clinical cut-off in the postpartum time points.

Correlations between repeated measures over time were moderate to high for both depression ($r = .40$–$.63$) and anxiety ($r = .40$–$.72$). Correlations between actiography and diary-based measures were high for sleep duration ($r = .57$) and moderate for WASO ($r = .38$). The number of rooms in the house was positively correlated with sleep duration during pregnancy ($r = .15$, $p = .02$), and negatively correlated with depression symptoms at 18-months postpartum ($r = -.19$, $p = .02$). Moreover, maternal age was positively correlated with WASO at 3-months postpartum ($r = .15$, $p = .03$), and depression symptoms at 6- ($r = .15$, $p = .04$) and 18-months ($r = .19$, $p = .02$) postpartum.

3.2 | Unconditional bivariate growth curve model

A bivariate growth curve was tested to examine the intercepts, slopes, and variances of depression and anxiety symptoms over four points at 3-, 6-, 12- and 18-months postpartum. The model with a linear term for depression and a quadratic term for anxiety fit the data significantly better than the model with linear terms only, $\Delta\chi^2$ (6) = 21.27, $p = .001$. The final unconditional bivariate growth curve model had excellent fit, χ^2 (12) = 11.46, $p = .49$; CFI = 1.000; RMSEA = 0.000; SRMR = 0.037. Depression symptomology had a significant intercept, $B = 3.48$, $p < .001$, and slope $B = -0.03$, $p = .032$. Anxiety symptomology had a significant intercept, $B = 3.85$, $p < .001$, slope, $B = -0.17$, $p = .008$, and quadratic growth term, $B = 0.01$, $p = .018$. The variance of the intercept for both depression and anxiety was significant ($p < .001$), as well as the variance for the anxiety slope ($p = .005$). The variance of the anxiety symptomology quadratic growth term exhibited a non-significant trend ($p = .079$). The variance of the depression symptomology slope and quadratic term were non-significant.

3.3 | Growth mixture modelling

To determine the optimal number of classes of depression and anxiety symptomology, the final bivariate growth model was run with two through five classes. The class solutions and fit indices are presented in Table 2. The four-class solution was the optimal solution, based on the lower AIC and BIC than the three-class solution. The BLRT and the LMR-LRT tests did not differentiate between class solutions. Although the five-class solution exhibited good statistical fit

TABLE 2 Fit of growth mixture models

	Information criteria				Likelihood ratio test, *p*	
No. of classes	AIC	BIC	SABIC	Entropy	BLRT	LMR-LRT
2-class	6,599.843	6,675.589	6,602.724	0.97	<.001	.287
3-class	6,481.188	6,576.694	6,484.820	0.88	<.001	.136
4-class	**6,406.271**	**6,521.537**	**6,410.655**	**0.87**	**<.001**	**.181**
5-class	6,349.042	6,484.067	6,354.177	0.89	<.001	.450

Note: Chosen class is shown in bold.

Abbreviations: AIC, Akaike information criterion; BIC, Bayesian information criteria; BLRT, the bootstrapped likelihood ratio test; LMR-LRT, Lo–Mendell–Rubin adjusted likelihood ratio test; SABIC, sample-size adjusted BIC.

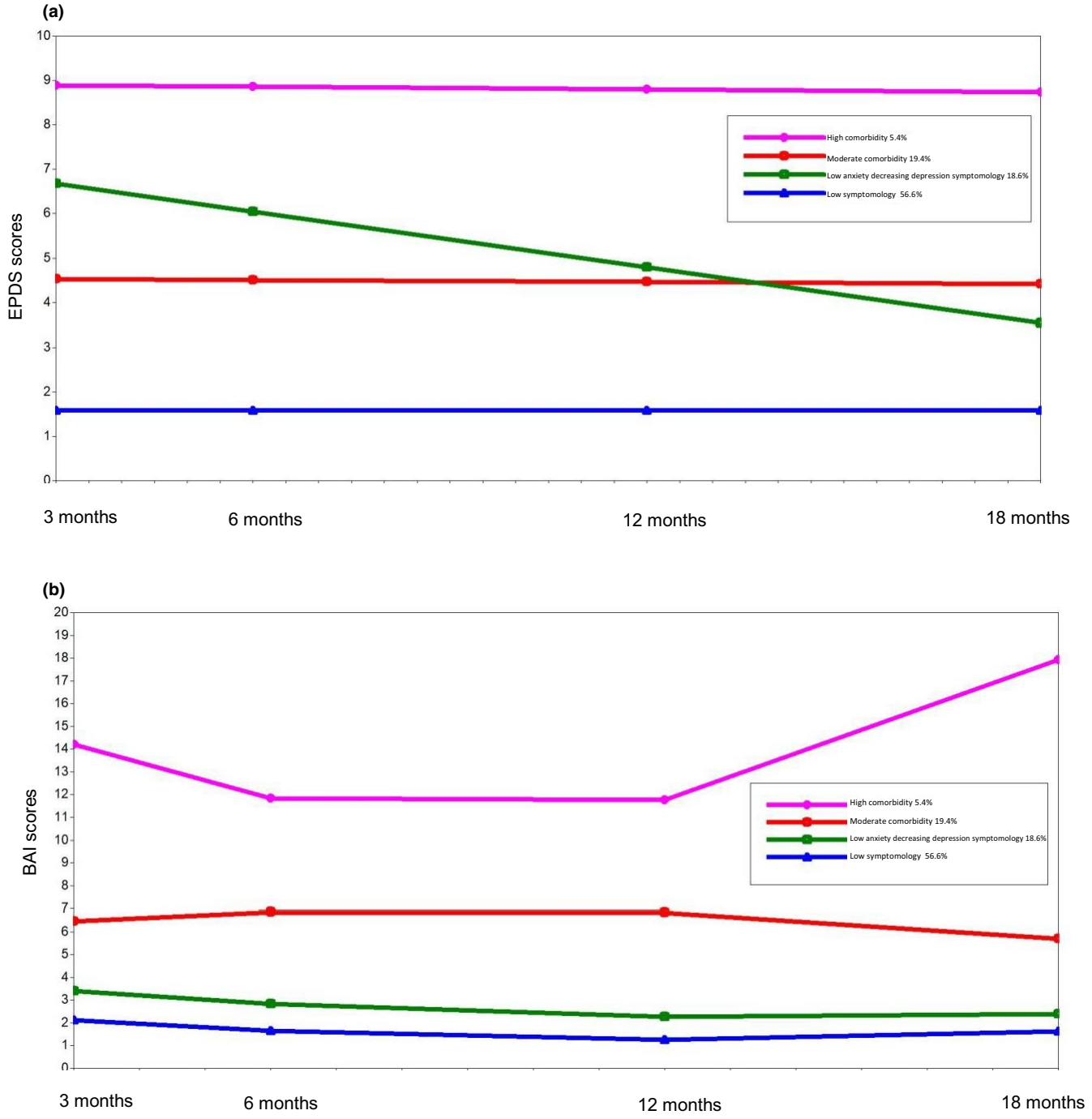

FIGURE 1 Estimated mean trajectories of (a) depressive symptoms; (b) anxiety symptoms from 3- to 18-months postpartum for each class. BAI, Beck Anxiety Inventory; EPDS, Edinburgh Postnatal Depression Scale

criteria in terms of entropy, AIC, and BIC, it included a class with <3% of the sample, which may have limited generalisability (Wickrama et al., 2016). Thus, we chose the four-class solution that included the *high comorbidity* class (5.4% of sample), showing elevated depressive and anxiety symptoms throughout the first 18-months postpartum; the *moderate comorbidity* class (19.4% of sample), showing moderate levels of depressive and anxiety symptoms; the *low anxiety decreasing depression symptomology* class (18.6% of sample), showing initially moderate but decreasing depressive symptoms and low stable anxiety symptoms; and the *low symptomology* class (56.6% of sample), showing stable low depressive symptoms and decreasing low anxiety symptoms. See Figure 1 for a graphic display of the growth curves for depression and anxiety in each class, and Table 3 for the intercept and growth curve characteristics of each class.

3.4 | Multinomial regression

The associations between the covariates, predictors and class membership were assessed by a series of multinomial regression analyses

TABLE 3 Growth factor parameter estimates for four-class unconditional model

Class	Depression symptoms, Est. (*SE*)		Anxiety symptoms, Est. (*SE*)		
	Intercept	Slope	Intercept	Slope	Quadratic
High comorbidity	8.887***	−0.010	14.199***	−1.048*	0.086**
Moderate comorbidity	4.524***	−0.007	6.453***	0.184	−0.016
Low anxiety decreasing depression symptomology	6.674***	−0.209**	3.400***	−0.216	0.010
Low symptomology	1.577***	0.000	2.132***	−0.19**	0.010**

Abbreviations: Est., estimate; *SE*, standard error.

*$p < .05$;

**$p < .01$;

***$p < .001$.

(Table 4). Separate equations were estimated for actiography and diary-based sleep measures. The low symptomology class was chosen as the reference class.

Overall, mothers with longer sleep durations during pregnancy were less likely to belong to the high comorbidity class or the moderate comorbidity class compared to the low symptomology class. This pattern of results was similar for the actiography and diary-based sleep measures. Both actiography and diary-based measures of WASO during pregnancy were not significant predictors of class membership.

The sleep duration measures at 3-months postpartum were not significant predictors of class memberships. However, diary-based WASO at 3-months postpartum was a significant predictor of class belonging: mothers with higher WASO were more likely to belong to the moderate comorbidity class compared to the low symptomology class. Actiography-based WASO showed a similar non-significant trend ($p = .055$).

4 | DISCUSSION

The present study expands the accumulating evidence on the pivotal role of sleep during pregnancy in postpartum adjustment. It is the first to assess these longitudinal links using both objective and subjective measures of sleep, and employ a bivariate trajectory-based approach to capture patterns of changes in depression and anxiety symptoms from 3- to 18-months postpartum. We found that sleep duration during pregnancy significantly predicted class membership to the high and moderate comorbidity classes. In addition, sleep quality (i.e. WASO) at 3-months postpartum (but not during pregnancy) was predictive of class membership to the moderate comorbidity symptoms class.

Shorter sleep duration during pregnancy, as measured by both objective and subjective measures, increased the odds of belonging to the high and moderate postpartum comorbidity classes, compared to the low symptomology class. These findings extend previous research in two ways. First, demonstrating that objective measures of sleep predict emotional distress addresses a main limitation reported by previous research, and challenges the alternative explanation that more depressed subjects are negatively biased in their subjective ratings of sleep. With that said, this alternative explanation can account for the relatively larger ORs for the subjective sleep measures compared to the objective measures in predicting class membership. The subjective measures may be stronger predictors of class belonging due to the tendency of depressed and anxious individuals to over report sleep problems. Second, rather than predicting emotional distress in isolated time points (Park et al., 2013), we showed that short sleep duration may have enduring effects on trajectories of emotional distress.

Although WASO during pregnancy was not a significant predictor of class belonging, our present results show that mothers with higher WASO (i.e. longer wake time after sleep onset) at 3-months postpartum were more likely to belong to the moderate comorbidity symptoms class compared to the low symptomology class. This finding may be explained by the increase in WASO between the prenatal and postpartum periods: both objective and subjective sleep measures showed that WASO minutes doubled between these time periods. It is possible that WASO becomes a more prominent factor in the postpartum period, during which mothers are awake for extensive stretches of time during the night in order to care for their newborn infants. However, these findings should be interpreted with caution because they are based only on the subjective WASO measure. The objective WASO measure showed a non-significant trend in predicting class belonging. Including more nuanced measures of sleep quality such as sleep efficiency and sleep fragmentation during pregnancy could have perhaps resulted in a more comprehensive assessment of sleep quality and different associations with emotional distress trajectories.

Although our present findings are generally consistent with previous research, some discrepancies in the predictive aspects of sleep were evident. For example, most previous studies reported that low sleep quality during pregnancy was related to postpartum depression (Tomfohr et al., 2015), whereas in the present study only sleep duration predicted trajectories of depressive symptoms. One explanation for these inconsistent findings may be the different measures used in the studies. Previous studies mainly relied on self-report measures of sleep, that yield an overall measure of sleep quality without differentiating between different aspects of sleep. As mentioned above, the WASO measure may not be an optimal

TABLE 4 Multinomial logistic regression coefficients, odds ratios (ORs) and confidence interval (CIs) for predictors of class belonging

		High comorbidity versus low symptomology		Moderate comorbidity versus low symptomology		Low anxiety decreasing depression symptomology	
		Logit (OR)	95% CI	Logit (OR)	95% CI	Logit (OR)	95% CI
Actiography sleep measures	Sleep duration PR	−0.02 (0.98)*	−0.05 to −0.01	−0.02 (0.98)**	−0.04 to −0.01	−0.008 (0.99)	−0.02 to 0.01
	WASO PR	0.00 (1.00)	−0.02 to 0.02	−0.01 (0.99)	−0.04 to 0.01	−0.005 (0.99)	−0.12 to 0.11
	Depression PR	0.30 (1.36)	−0.12 to 0.74	0.11 (1.11)	−0.15 to 0.37	0.34 (1.40)**	0.32 to 0.36
	Anxiety PR	0.22 (1.24)**	0.11 to 0.34	0.21 (1.23)**	0.07 to 0.36	0.02 (1.02)	−0.20 to 0.24
	Maternal age	−0.08 (0.92)	−0.34 to 0.17	−0.02 (0.98)	−0.18 to 0.14	0.10 (1.10)	−0.08 to 0.28
	Number of rooms in household	0.57 (1.76)	−0.72 to 1.87	−0.76 (0.46)*	−1.36 to −0.16	0.23 (1.25)	−0.36 to 0.82
	Sleep duration 3m	0.005 (1.00)	−0.01 to 0.02	0.009 (1.00)	0.00 to 0.02	0.000 (1.00)	−0.01 to 0.02
	WASO 3m	−0.02 (0.98)	−0.06 to 0.02	0.01 (1.01)****	0.00 to 0.03	0.004 (1.00)	−0.02 to 0.02
Diary sleep measures	Sleep duration PR	−1.54 (0.21)**	−2.59 to −0.51	−0.89 (0.41)*	−1.60 to −0.18	−0.38 (0.68)	−1.32 to 0.56
	WASO PR	−0.01 (0.99)	−0.03 to 0.01	−0.02 (0.98)****	−0.04 to 0.00	−0.002 (0.99)	−0.02 to 0.02
	Depression PR	0.27 (1.30)	−0.06 to 0.60	0.19 (1.20)	−0.06 to 0.44	0.41 (1.50)**	0.14 to 0.68
	Anxiety PR	0.27 (1.30)***	0.13 to 0.41	0.17 (1.18)*	0.03 to 0.31	−0.003 (0.99)	−0.12 to 0.11
	Maternal age	−0.23 (0.79)	−0.47 to 0.01	−0.09 (0.91)	−0.27 to 0.09	0.08 (1.08)	−0.10 to 0.26
	Number of rooms in household	−0.34 (0.71)	−1.48 to 0.79	−0.94 (0.39)**	−1.63 to −0.25	0.09 (1.09)	−0.52 to 0.70
	Sleep duration 3m	−0.06 (0.94)	−1.12 to 1.00	0.57 (1.76)	−0.16 to 1.30	−0.22 (0.80)	−0.85 to 0.41
	WASO 3m	0.13 (1.13)	0.07 to 0.19	0.10 (1.10)**	0.04 to 0.16	0.03 (1.03)	−0.03 to 0.09

Abbreviations: 3m, 3-months postpartum period; PR, pregnancy; WASO, wake after sleep onset.

*$p < .05$.

**$p < .01$.

***$p < .001$.

****$p < .10$.

measure for sleep quality during pregnancy. In addition, previous studies that also used actiography measures of sleep duration and quality (Park et al., 2013), including a previous report from the present study (Volkovich et al., 2016) found no concurrent associations between sleep duration and depressive symptoms. It may be that shorter sleep duration *perpetuates*, rather than triggers, depressive symptoms, as inferred by findings from the trajectory-based models in the present study. This notion is consistent with a study showing that patients diagnosed with major depressive disorder with persistent insomnia were 1.8–3.5-times more likely to remain depressed, compared with patients with no insomnia (Pigeon et al., 2008).

Findings from the present study support previous research indicating that insufficient sleep may be a risk factor for experiencing higher postpartum depressive and anxiety symptomology (Baglioni et al., 2011; Hertenstein et al., 2019). Although the mechanisms underlying these links are currently not well understood, we discuss common mechanisms that can underlie these processes.

Physiological hyperarousal (e.g. abnormal hormone secretion, and elevated autonomic nervous system activation) is a known biomarker for sleep disorders (Bonnet & Arand, 2010), which is also associated with depression and anxiety disorders (Joiner et al., 1999; Wong et al., 2000). In contrast, during pregnancy there are substantial changes in the cardiovascular and endocrine systems that are characterised by dampened physiological responses to stress (e.g. Braeken et al., 2015). It has been suggested that these normative changes support fetal development and maternal well-being, and are critical for priming the maternal brain for the challenges of motherhood (Christian, 2012). Women who have insufficient sleep may not show the expected decrease in stress reactivity due to heightened levels of arousal, and as a result may be at increased risk for unadaptable trajectories of emotional distress.

Heightened levels of circulating inflammatory markers are an additional proposed mechanism by which insufficient sleep might increase the risk for postpartum emotional distress (Chang et al., 2010). Both sleep disturbances and depressive symptoms have been associated with augmentation of inflammatory responses as indicated by increased concentrations of the pro-inflammatory cytokines, interleukin (IL)-6 and tumour necrosis factor (TNF)-α, and the acute phase protein, during pregnancy and the postnatal period (Christian et al., 2009; Taveras et al., 2011). During pregnancy, a contrasting process normally occurs in which inflammatory responses are generally attenuated to maintain normal gestation and delivery (Okun, 2019). It is possible that insufficient sleep during pregnancy disrupts the typical course of inflammatory switch off during pregnancy, leading to unfavourable maternal outcomes (Okun, 2019), including elevated emotional distress.

5 | LIMITATIONS AND CONCLUSIONS

Several limitations of the present study should be noted. First, we used a community sample that captured a highly-educated, low-risk population of women living in two-parent families with low rates of clinically significant depression and anxiety. Our present findings therefore cannot be generalised to high-risk populations, characterised by low SES, single-parent households or clinical levels of depression and anxiety. However, given the substantial proportion of women in the population that have subclinical symptoms of postpartum anxiety and depression, and the significant associations of these degrees of symptoms with adverse child outcomes (Kingston et al., 2018), we expect that trajectories of depression and anxiety as modelled in the present study will have important wide-spread implications for maternal and child well-being. Second, the present study was limited by self-reported measures of depression and anxiety symptoms. Although the EPDS and the BAI have been extensively used to assess depression and anxiety symptoms in the perinatal period, diagnostic interviews could detect aspects of emotional distress that are not disclosed in self-report measures, and further validate our findings. Finally, although our use of a five time-point longitudinal design is one of the study's strengths, it also increased attrition rates, which resulted in a moderate amount of missing data at the fourth and fifth time points.

Despite these limitations, findings from the present study contribute to the understanding of the unique role of sleep during pregnancy for subsequent emotional adjustment. Our present findings demonstrate that shorter sleep duration during pregnancy increases the odds of belonging to trajectory classes that typically display elevated and moderate levels of postpartum depression and anxiety symptoms. Given the potential negative implications of short sleep duration in pregnancy, healthcare providers who treat pregnant women should screen for sleep problems and intervene accordingly.

AUTHOR CONTRIBUTIONS

NG-S: Conceived the ideas for the manuscript, performed data analysis and interpretation, primary author. GS: Conceived the ideas for the manuscript, supervised data analysis and interpretation, provided revisions to scientific content of the manuscript. EV: Designed and conceptualised the study, performed data collection and analysis, provided revisions to scientific content of the manuscript. LT: Principal investigator, designed and conceptualised the study, provided funding, supervised data collection, provided revisions to scientific content of the manuscript.

DATA AVAILABILITY STATEMENT

The data are not publicly available due to privacy or ethical restrictions.

ORCID

Noa Gueron-Sela https://orcid.org/0000-0001-9826-5645

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