Subjective Perception of Sleep, but not its Objective Quality, is Associated with Immediate Postpartum Mood Disturbances in Healthy Women

Bei Bei, DPsych[1]; Jeannette Milgrom, PhD[1,2]; Jennifer Ericksen, MPsych[2]; John Trinder, PhD[1]

[1]School of Behavioural Science, University of Melbourne, Victoria, Australia; [2]Parent-Infant Research Institute, Austin Health, Victoria, Australia

Study Objectives: This study investigated whether there was a relationship between disrupted sleep and postpartum mood disturbances in women during the week after delivery.

Design: Sleep and mood were measured during the third trimester (Time-1) and one week postpartum (Time-2) in a 2-stage longitudinal design.

Setting: Participants were recruited from an antenatal clinic in a regional Melbourne hospital.

Participants: Forty-four healthy women at low risk for postpartum depression.

Interventions: N/A

Measurements and Results: Objective sleep was measured by actigraphy and subjective sleep by the Pittsburgh Sleep Quality Index; mood was assessed by the Depression Anxiety Stress Scale, the Hospital Anxiety Depression Scale, and the Positive and Negative Affect Schedule. Sleep and mood questionnaires were administered at Time-1 and Time-2. Wrist actigraphy was collected for one week at both times. After delivery, both objective and subjective nighttime sleep significantly worsened with decreased total sleep time and sleep efficiency, while daytime napping behavior significantly increased. On average, mood improved across all scales after delivery, although 45.95% of the sample experienced deterioration of mood. Regression analyses showed little relationship between Time-1 and Time-2 objective nighttime sleep, and postpartum mood. Variables that related to both Time-1 and Time-2 subjective perception of sleep, including subjective nighttime sleep, sleep-related daytime dysfunction, and daytime napping behavior, were significant predictors of postpartum mood.

Conclusions: The perception of poor sleep, and the conscious awareness of its impact during wake-time, might share a stronger relationship with the occurrence of immediate postpartum mood disturbances than actual sleep quality and quantity.

Keywords: Sleep, actigraphy, women, pregnancy, postpartum, mood, depression, anxiety

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CHILDBIRTH IS REGARDED AS A CRITICAL EVENT IN WOMEN'S LIVES THAT LEAVES THEM VULNERABLE FOR MOOD DISTURBANCES. APPROXIMATELY 30% TO 75% mothers experience a mild and transient mood disturbance called postpartum blues ("baby blues") a few days after delivery.[1,2] The blues usually dissipate within a week and are characterized by mood lability and tearfulness.[3,4] Other symptoms such as irritability, anxiety, headache, sleep disturbance, and lack of concentration are not uncommon.[4,5] Postpartum blues is differentiated from postpartum depression and postpartum psychosis, which are more severe psychiatric disorders that greatly impair daily functioning, and require therapeutic interventions. However, postpartum blues has been shown in some studies to increase the risk of postpartum depression.[6]

Pregnancy and birthing not only bring about hormonal and psychosocial changes, but also significantly alter new mothers' sleep-wake behaviors. Women in late pregnancy and early postpartum periods have consistently been shown to have less total sleep time (TST) and poorer sleep efficiency (SE) than non-pregnant healthy controls.[7] Pregnancy-related changes in sleep architecture are less clear, but an increase in slow wave sleep (SWS) postpartum, possibly associated with the extensive energy expenditure during labor, was observed by both earlier[8] and recent[9] investigations.

Considerable research suggests a bi-directional linkage between sleep disruptions and mood disturbances. Sleep problems are common among individuals with depression (up to 90%),[10] and sleep disruption is considered a prodromal symptom or predictor of a mood disorder.[11] While in healthy adults, acute sleep deprivation is associated with increased fatigue, irritability,[12] amplified negative emotion, and lessened positive responses,[13] it can paradoxically produce a transient antidepressant effect on people with depression.[14,15] Chronic sleep disruption caused by long-term partial sleep deprivation or sleep fragmentation on the other hand, has been consistently associated with worsened mood.[16,17]

Despite the growing body of literature on sleep and mood disorders, sleep disruption has rarely been examined as a contributing factor to pregnancy related mood disturbances. The few studies that investigated this relationship were largely based on subjective measurements of sleep. For example, Wilkie and Shapiro[18] found 2 sleep-related factors in the development of immediate postpartum mood disturbances: a nighttime labor and a history of subjective sleep disruption during the third trimester. Goyal and colleagues[19] followed up 124 nulliparous women and found that subjective sleep disturbance, especially delayed sleep onset, was associated with depressive symptoms during the third trimester and the third month postpartum. More recently, Skouteris and colleagues[20] surveyed 273 women during pregnancy and revealed that poor sleep quality earlier in pregnancy predicted higher levels of depressive symptoms at later stage in pregnancy. Given the discrepancy between sub-

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Address correspondence to: Bei Bei, DPsych, 12th Floor Redmond Barry, Department of Psychology, The University of Melbourne, Victoria 3010, Australia; Tel: +61 3 8344 4911; E-mail: beib@unimelb.edu.au

jectively and objectively assessed sleep in the literature,[21-23] studies that incorporate both methods are needed. However, such studies are rare. In a longitudinal study utilizing ambulatory polysomnography, Lee et al.[24] found that compared to mothers with positive affect, mothers reporting negative affect had generally slept less and had less stable sleep patterns at one month postpartum. Two recent studies investigated the relationship between sleep and postpartum depressive symptoms using actigraphy in cross-sectional designs: Posmontier[25] found that wrist actigraphy measured sleep (including sleep latency, wake after sleep onset, and SE) was worse among mothers with postpartum depression than those without. This was not confirmed by Dorheim et al.,[26] who found that at 2 months postpartum, depressed mothers reported poorer subjective sleep than nondepressed mothers, but the 2 groups did not differ significantly on their objective sleep.

Although compromised by limitations such as the lack of objective sleep measurements and the lack of longitudinal follow-up, these studies strongly suggest that sleep disturbances may have etiological significance for postpartum mood disturbances. This notion was further highlighted by reviews that called for systematic investigations of the potential relationship between objective measurement of sleep and postpartum mood.[27,28] In this study we employed both subjective and objective measurements of sleep with a longitudinal design. It was hypothesized that the degree of sleep impairment during pregnancy and immediate postpartum periods would be associated with the occurrence of mood disturbances.

METHODS

Participants

A total of 44 women with an average age of 30.41 years (SD = 5.59) were recruited in their third trimester (gestation week: M = 27.73, SD = 2.05) from an antenatal clinic at a regional hospital. They participated in this study on a voluntary basis after giving informed consent. All participants met the following selection criteria: (a) a low probability of current depression (< 12 on the Edinburgh Postnatal Depression Scale[29]); (b) no major medical complication accompanying the pregnancy at time of recruitment; (c) no history of severe psychiatric conditions; (d) not on any sleeping medication; and (e) not on nightshifts. These criteria took into account major risk factors for postpartum depression.[30] The sample included 20 (45.5%) nulliparas and 24 (54.5%) multiparas, and the majority (90.9%) of participants were married or in a stable relationship.

Design

This was a 2-stage longitudinal study in which participants were assessed for sleep and mood during the third trimester (Time-1) and the first postpartum week (Time-2). Subjective sleep and mood scales were administered on both occasions, and objective sleep data was recorded continuously for 7 days during Time-1, and 7 days after delivery.

Procedures

Once recruited at Time-1, participants were given a wrist-actigraph and a questionnaire pack that included the Demographic/Psychosocial Questionnaire (DPQ-1), the Pittsburgh Sleep Quality Index (PSQI), the Positive Negative Affect Schedule (PANAS), the Hospital Anxiety Depression Scale (HADS), and the Depression Anxiety Stress Scale (DASS). They completed and returned the questionnaires on the day of recruitment and were asked to wear the wrist-actigraph continuously (during both day and night) for 7 days before returning it to the research laboratory by mail. Participants were instructed to press the Event Marker on the actigraph when they went to bed and when they got up, for both nighttime sleep and daytime naps.

Two weeks prior to their due dates, participants received an actigraph and a second questionnaire pack (DPQ-2, PANAS, HADS, DASS, PSQI) by mail. Those who were expecting to have natural births were asked to put on the actigraph one week before their due dates or whenever labor began (if it started earlier than that). Women who had scheduled Caesarean births were asked to put on the actigraph before their Caesarean appointments. All participants were reminded by phone when they had to put on the actigraph and were asked to wear it continuously until one week postpartum. At the end of the first postpartum week, they completed the second questionnaire pack and returned it with the actigraph to the research laboratory by mail.

Attrition

All 44 participants completed the first questionnaire pack. Third trimester actigraphy data was not obtained from 3 (6.82%) participants: 2 did not wear the actigraph due to inconvenience at work; one due to skin irritation caused by the wristband. During the second assessment, questionnaire data was not available from 6 (13.64%) women: 5 did not return the questionnaire; one could not be contacted using previously supplied details. Postpartum actigraphy data was not obtained from 16 (36.37%) participants: 2 gave birth more than 2 weeks earlier than due dates; 3 did not wear the actigraph due to medical complications; the remaining 11 (25%) did not wear the actigraph because they found it inconvenient or uncomfortable. A series of statistical comparisons using one-way analyses of variance (ANOVA) and χ^2 tests did not show significant difference over all Time-1 measurements (i.e., sociodemographic variables and antenatal sleep/mood) between those who did not wear the actigraph at Time-2 and those who did.

Equipment and Materials

Sleep

Actigraphy (Actiwatch-64, Mini Mitter, Oregon, USA) was chosen as the objective measurement of sleep in this study because many studies have consistently shown high correlations when comparing it against polysomnographically measured sleep parameters. [31] It also allowed extended periods of home monitoring of the sleep/wake patterns of women in late pregnancy and early postpartum periods.

The Pittsburgh Sleep Quality Index[32] was used to measure subjective perception of sleep prior to pregnancy (Time-0) retrospectively, as well as at Time-1 and Time-2, with one added item on the number and duration of daytime naps. It is a well-validated[33] self-report questionnaire that covers both the physical and psychosocial domains of sleep dysfunctions.[34] The Cronbach α for Time-0, Time-1, and Time-2 were 0.74, 0.73, and 0.75, respectively.

Mood and affect

The Depression Anxiety Stress Scale (DASS): The DASS is a well validated self-report measure of depression, anxiety, and stress,[35] and was selected because it not only measures a series of anxiety and depressive symptoms, but also provides information on the stress women perceive during and after pregnancy. In this study, the 21-item version was used with each of the three subscales consisting of 7 items that are responded to on a 0-3 scale. Cronbach α levels for depression, anxiety, and stress subscales were 0.75, 0.68, and 0.77 at Time-1, and 0.71, 0.71, and 0.78 at Time-2.

The Hospital Anxiety and Depression Scale (HADS): The HADS identifies and measures severity of depression and anxiety in non-psychiatric clinical environments with high validity, sensitivity, and specificity.[36] HADS was chosen in this study as it minimizes influence from somatic discomfort during pregnancy on the scores by excluding physical symptoms of anxiety and stress. The HADS consists of 14 items of which 7 measure depression and the other 7 anxiety. In this study, the Cronbach α for anxiety and depression scales were both 0.75 at Time-1; 0.74 and 0.76 respectively at Time-2.

The Positive Negative Affect Schedule (PANAS): Positive affect (PA) represents the extent to which an individual experiences pleasurable engagement with the environment; negative affect (NA) is epitomized by subjective distress and non-pleasurable engagement. The PANAS is a 20-item self-report that is designed to provide independent measure of positive and negative affects.[37] The authors have reported the scales to be internally consistent, largely uncorrelated, and stable at appropriate levels over a 2-month time period. In this study, Cronbach α for positive and negative affects were both 0.77 at Time-1 and were both 0.77 at Time-2.

Data Reduction

Actigraphy

All actigraphy data were recorded using one-minute epoch length and processed in Actiware 5.02 based on *Medium* (i.e., 40) threshold. Sleep/wake and mobility patterns were analyzed for each 24-h cycle (18:00 till next day 17:59), and recordings that did not cover a full 24-h cycle were excluded from all analyses. *Nighttime sleep* was defined as a sleep period that was continuous with the participant's circadian sleep phase, as reported by participants as their habitual bedtime/rise-time in the third trimester. A *nap* was defined as an independent (i.e., not a continuation of night time sleep) sleep episode that occurred within a person's habitual wake time. The following statistical variables were generated for nighttime sleep by the Actiware using standard settings: (a) total sleep time (TST_{acti}), (b) wake after sleep onset ($WASO_{acti}$), (c) sleep efficiency (SE_{acti}), (d) sleep disturbance (SD_{acti}), and (e) average immobile bouts duration to indicate sleep fragmentation (SF_{acti}). Total sleep time and wake after sleep onset were the total number of minutes the actigraph scored "sleep" or "wake" for a given sleep interval. Immobile bouts were defined as continuous blocks, one or more epochs in duration, with each epoch of each block scored as *immobile.* Average durations of immobile bouts during a sleep interval indicate the degree of sleep fragmentation: shorter average immobile bouts indicate higher sleep fragmentation. The SD_{acti}, labeled in the Actiware as the *Sleep Fragmentation Index*, was a summed percentage of mobile time and immobile bouts less than one minute in duration for a given time-in-bed interval. As this calculation reflected sleep disturbance caused by *both* physical discomfort/restlessness (i.e., sleep fragmentation in the sleep literature) *and* sleep disruptions caused by awakening from sleep (going to bathroom, feeding the baby), it was named *Sleep Disturbance* in this study, conceptually comparable to sleep disturbance scores provided by PSQI. The occurrence of naps was determined by event markers whenever they were available. On occasions when participants forgot to enter nap information, daytime naps were calculated manually by screening minute-by-minute sleep/wake scores during participant's habitual wake-time. Sleep episodes longer than 10 minutes were considered to be naps. If onset of a second sleep episode occurred ≤ 15 minutes after waking from a previous one, they were combined and considered to represent one nap; nap duration was calculated as the total number of minutes scored as sleep during a nap. Average nap duration ($Napt_{acti}$) was calculated by dividing total daily nap time (TNT_{acti}) by daily nap number ($Napn_{acti}$).

Questionnaires

The following components were derived from PSQI according to standardized scoring procedures recommended by the authors of the questionnaire: total sleep time (TST_{psqi}), sleep onset latency (SL_{psqi}), sleep efficiency (SE_{psqi}), sleep disturbances/fragmentation (SD_{psqi}), subjective sleep quality ($Quality_{psqi}$), and sleep-related daytime dysfunction ($Dysfunction_{psqi}$, e.g. "how often have you had trouble staying awake while…?"). The total score of these components indicated participants' perceived overall sleep quality ($PSQI_{total}$). In computing descriptive statistics, the actual values of TST_{psqi}, SL_{psqi}, and SE_{psqi} were used whereas other components were scaled scores ranging from 0 to 3, with high scores indicating poor sleep. Mood variables were derived from standard scoring procedures of DASS-21, HADS, and PANAS. Results presented below were based on the raw scores of the DASS-21.

Statistical Analyses

Changes in sleep and mood were examined using paired-samples *t*-tests and repeated measures ANOVA. Regression analyses were used to examine whether there was a relationship between sleep and mood. The following sleep models (for multiple regressions) and predictors (for linear regressions) were used to predict mood at Time-1 and Time-2: (a) nighttime objective model, (b) nighttime subjective model, (c) daytime objective predictor ($Napn_{acti}$), and (d) daytime subjective predictor ($Dysfunction_{psqi}$). Each nighttime model included a set of variables that were chosen as being representative of objective or subjective sleep quality at night. Sample size limited the number of variables allowed in regression analyses, and at the same time discouraged the use of factor analyses to reduce the number of variables. Therefore selections of these predicting variables were based on theoretical considerations as to whether a variable represented a unique aspect of sleep quality or quantity. Variables included in the objective nighttime model were TST_{acti}, SE_{acti}, and SF_{acti}; while variables included in the subjective nighttime model were TST_{psqi}, SL_{psqi}, SD_{psqi}, and

Table 1—Means and standard deviations of mood and sleep variables prior to pregnancy, third trimester, and one week postpartum

	Prior to Pregnancy	3rd Trimester	Postpartum
Mood (*N* = 37)			
$DASS_{total}$	N/A	8.30 ± 6.45	6.97 ± 6.10
$DASS_{depression}$	N/A	2.16 ± 2.60	1.22 ± 1.57*
$DASS_{anxiety}$	N/A	1.92 ± 1.88	1.70 ± 2.08
$DASS_{stress}$	N/A	4.22 ± 3.37	4.05 ± 3.79
$HADS_{total}$	N/A	8.46 ± 5.36	6.51 ± 4.87*
$HADS_{depression}$	N/A	3.59 ± 2.99	3.00 ± 2.71
$HADS_{anxiety}$	N/A	4.86 ± 3.15	3.51 ± 2.70**
PA	N/A	33.51 ± 7.56	37.51 ± 7.45**
NA	N/A	15.57 ± 5.92	15.46 ± 5.90
Objective Sleep (*N* = 28)			
TST_{acti} (min)	N/A	428.39 ± 45.21	372.57 ± 73.85*
$WASO_{acti}$ (min)	N/A	77.11 ± 25.05	149.66 ± 44.57**
SE_{acti} (%)	N/A	76.88 ± 6.13	62.60 ± 9.89**
SD_{acti} (%)	N/A	37.01 ± 10.24	52.42 ± 12.83**
SF_{acti} (min)	N/A	8.72 ± 2.59	9.02 ± 2.53**
$Napn_{acti}$	N/A	0.77 ± 0.66	3.18 ± 1.01**
$Napt_{acti}$ (min)	N/A	34.65 ± 21.55	31.72 ± 14.40
TNT_{acti} (min)	N/A	31.70 ± 36.79	100.69 ± 58.33**
Subjective Sleep (*N* = 37)			
TST_{psqi} (min)	474.73 ± 68.03	436.62 ± 74.82††	347.68 ± 106.86††**
SL_{psqi} (min)	17.89 ± 12.26	29.19 ± 22.10††	16.32 ± 12.18**
SE_{psqi} (%)	90.42 ± 7.75	79.16 ± 11.49††	65.78 ± 18.62††**
SD_{psqi}	0.81 ± 0.40	1.57 ± 0.60††	1.51 ± 0.61††
$Quality_{psqi}$	0.49 ± 0.56	1.16 ± 0.65††	1.19 ± 0.78††
$Dysfunction_{psqi}$	0.43 ± .55	0.784 ± .63††	0.84 ± 0.83††
$PSQI_{total}$	2.84 ± 2.03	6.90 ± 2.92††	8.05 ± 3.84††

*P < 0.05, **P < 0.01 when compared to Time-1 values; ††P < 0.01 when compared to Time-0 values. DASS, Depression Anxiety Stress Scale; HADS, Hospital Anxiety Depression Scale; PA, Positive Affect; NA, Negative Affect; "$_{acti}$", actigraphy-measured variables; TST, total sleep time; WASO, wake after sleep onset; SE, sleep efficiency; SD, sleep disturbance; SF, sleep fragmentation; Napn, daily nap number; Napt, daily average nap duration; TNT, total daily nap time. PSQI, Pittsburgh Sleep Quality Index; SL, sleep onset latency; $Quality_{psqi}$, PSQI overall sleep quality; $Dysfunction_{psqi}$,PSQI sleep-related daytime dysfunction; DASS scores were based on the DASS-21 raw scores.

$Quality_{psqi}$. Mood during the third trimester was correlated with Time-1 sleep models and predictors; mood during the first week postpartum was correlated with both Time-1 and Time-2 sleep models and predictors. Multiple regression analyses were performed on each mood scale using the *enter* method. The daytime sleep predictors $Napn_{acti}$ and $Dysfunction_{psqi}$ were analyzed by linear regression analyses.

RESULTS

Changes in Mood

There was a general improvement of mood post childbirth across all scales (Table 1). The HADS total scores were significantly lower at Time-2 than at Time-1, while the total scores of DASS did not differ significantly. On individual subscales, both the DASS-measured depression and HADS-measured anxiety were significantly lower at Time-2 than at Time-1. Other DASS and HADS subscale scores did not show statistically significant changes over time. There were also changes in positive affect. Participants reported significantly higher PA during the postpartum period than during the third trimester; their reported negative affect was low at both times compared to normative data.[38]

While mood improved after delivery on average, it was not the case for each individual. Women were defined as experiencing poor mood if they had deterioration on ≥ 2 HADS or PANAS subscales, with at least one of the deteriorations occurring on HADS or its subscales. The DASS scores were not taken into account for this classification, as the somatic symptoms they include might have confounded findings among late-term and early postpartum women. Seventeen (45.95%) women were identified as having more negative mood using above criteria, suggesting that a sufficiently large percentage of the sample experienced some deterioration of mood, allowing further examination of the hypotheses.

Changes in Sleep

As illustrated in Table 1, objective sleep deteriorated after delivery. There was a significant decrease in TST_{acti} and increase in $WASO_{acti}$ from Time-1 to Time-2. Sleep was also more disrupted after delivery, with postpartum SE significantly lower and sleep disturbance significantly higher than measured during the third trimester. Sleep fragmentation did not differ significantly, suggesting that restlessness in bed was similar at both times. Participants spent significantly more time napping at Time-2 than at Time-1, an increase of over 3-fold. This increase was due to participants taking more naps rather than an increase in average nap duration, as daily nap number at Time-2 was > 4 times higher than that of Time-1, while average nap durations did not differ significantly. Interestingly, no difference was found when TST over 24 h (i.e., the sum of TST_{acti} and TNT_{acti}) was compared between Time-1 and Time-2, $t_{27} = 0.62$, P = 0.54.

Subjective sleep values were compared at Time-0, Time-1, and Time-2, with mean values presented in Table 1. Compared to non-pregnant baseline values, subjective sleep was worse during and immediately after pregnancy, with significantly decreased TST_{psqi}, SE_{psqi}, and significantly increased reports of sleep disturbances as well as sleep related daytime dysfunction. Subjective sleep also worsened from Time-1 to Time-2, as both TST_{psqi} and SE_{psqi} decreased significantly after delivery. There was some deterioration on PSQI-measured sleep disturbance, perceived quality, and sleep related daytime dysfunction from Time-1 to Time-2, but the changes were not statistically significant. Sleep latency during the third trimester was significantly longer than before and immediately after pregnancy, with no significant difference between the latter two.

Subjective TST is conceptually equivalent to that measured by actigraphy. However, linear correlation analyses showed no significant correlation between TST_{psqi} and TST_{acti}, nor did paired-samples *t*-tests show any significant difference between them at either Time-1 or Time-2. Subjective SE applies to *time-in-bed* rather than *sleep intervals* as in SE_{acti}, and is therefore expected to be *lower* than SE_{acti}, as it takes into account both sleep latency and snooze time, while SE_{acti} does not. However, partic-

ipants subjectively *over*-estimated sleep efficiency, as average SE_{psqi} was higher than SE_{acti} at both Time-1 and Time-2, even though these differences were not significant when tested using paired-sample *t*-tests. As in TST, linear correlation analyses also showed no significant correlation between SE_{psqi} and SE_{acti} at either time.

Sleep and Mood

Sleep and third trimester mood

Nighttime: Statistical results of regression analyses are presented in Table 2. Multiple regression analyses did not show a statistically significant result in predicting third trimester mood using selected third trimester objective nighttime sleep variables. In contrast, subjective perception of nighttime sleep during the third trimester consistently predicted third trimester mood as measured by $HADS_{total}$, PA, and NA. Third trimester subjective sleep accounted for 27% of the variance in $HADS_{total}$ (23% for both its subscales), 22% in PA, and 26% in NA measured at Time-1. When physical symptoms of mood were included, as in the DASS scales, third trimester mood was no longer related to third trimester subjective nighttime sleep variables at a statistically significant level.

Table 2—Summary of regression analyses predicting third trimester and postpartum mood using various measurements of sleep behavior

	Nighttime Sleep				Daytime Sleep			
	Objective (TST_{acti}, SE_{acti}, SF_{acti})		Subjective (TST_{psqi}, SL_{psqi}, SD_{psqi}, $Quality_{psqi}$)		Objective ($Napn_{acti}$)		Subjective ($Dysfunction_{psqi}$)	
	3rd Trimester	Post-partum	3rd Trimester	Post-partum	3rd Trimester	Post-partum	3rd Trimester	Post-partum
Third trimester mood								
$DASS_{total}$	0.12	N/A	0.08	N/A	0.04	N/A	0.30**	N/A
$DASS_{depression}$	0.05	N/A	0.07	N/A	0.01	N/A	0.13*	N/A
$DASS_{anxiety}$	0.14	N/A	0.07	N/A	0.02	N/A	0.10*	N/A
$DASS_{stress}$	0.08	N/A	0.07	N/A	0.04	N/A	0.32**	N/A
$HADS_{total}$	0.07	N/A	0.27*	N/A	0.06	N/A	0.42**	N/A
$HADS_{depression}$	0.06	N/A	0.23*	N/A	0.05	N/A	0.33**	N/A
$HADS_{anxiety}$	0.06	N/A	0.23*	N/A	0.04	N/A	0.31**	N/A
PA	0.03	N/A	0.22*	N/A	0.01	N/A	0.34**	N/A
NA	0.15	N/A	0.26*	N/A	0.06	N/A	0.40**	N/A
Postpartum mood								
$DASS_{total}$	0.06	0.01	0.15	0.15	0.04	0.25**	0.01	0.07
$DASS_{depression}$	0.16	0.01	0.11	0.11	0.02	0.05	0.004	0.01
$DASS_{anxiety}$	0.06	0.08	0.04	0.10	0.05	0.19*	0.01	0.01
$DASS_{stress}$	0.03	0.04	0.17	0.22	0.02	0.20*	0.02	0.11*
$HADS_{total}$	0.14	0.05	0.25*	0.31*	< 0.001	0.11	0.18**	0.22**
$HADS_{depression}$	0.18	0.08	0.27*	0.35**	< 0.001	0.08	0.10	0.24**
$HADS_{anxiety}$	0.08	0.02	0.19	0.22	< 0.001	0.11	0.21**	0.13*
PA	0.25*	0.06	0.20	0.39**	0.002	0.07	0.20**	0.18**
NA	0.09	0.05	0.19	0.22	< 0.001	0.21*	0.09	0.15*

Values in cells are R^2. *P < 0.05, **P < 0.01 poorer sleep or greater worsening of sleep was associated with higher mood disturbances. DASS, Depression Anxiety Stress Scale; HADS, Hospital Anxiety Depression Scale; PA, Positive Affect; NA, Negative Affect; TST_{acti},actigraphy total sleep time; SE_{acti},actigraphy sleep efficiency; $SF_{acti,}$ actigraphy sleep fragmentation; PSQI=Pittsburgh Sleep Quality Index; TST_{psqi}, PSQI total sleep time; SL_{psqi}, PSQI sleep onset latency; SD_{psqi}, PSQI sleep disturbance; $Quality_{psqi}$, PSQI overall sleep quality; $Napn_{acti}$, actigraphy daily nap number; $Dysfunction_{psqi}$, PSQI sleep-related daytime dysfunction.

Daytime: Daily nap number during the third trimester did not significantly predict third trimester mood, while all third trimester mood variables were strongly associated with sleep related daytime dysfunction measured by PSQI. In general, DASS was related to $Dysfunction_{psqi}$ to a lesser extent than other mood scales. Third trimester $Dysfunction_{psqi}$ explained approximately 30% of the variance in third trimester DASS total scores, an effect possibly related to its contribution to the stress subscale (32%) rather than the depression (13%) or anxiety (10%) subscales. When somatic symptoms of mood were excluded, as in HADS and PANAS, third trimester $Dysfunction_{psqi}$ provided a good prediction of mood states with R^2 ranging from 0.31 to 0.42 (all P < 0.001).

Sleep and postpartum mood

Nighttime: Third trimester, but not postpartum, objective nighttime sleep contributed significantly to postpartum positive affect, with poorer sleep associated with lower PA. Other postpartum mood variables were not significantly related to any objective nighttime sleep predictors. Postpartum subjective nighttime sleep successfully predicted postpartum $HADS_{depression}$ and PA, making 35% and 39% contributions to their variance, respectively. Poorer third trimester subjective sleep was also shown to be associated with worse postpartum $HADS_{total}$ (R^2 = 0.25), in particular, its depression subscale.

Daytime: Daily nap numbers during the postpartum period successfully predicted postpartum DASS measured mood (in particular the anxiety and stress subscales) and negative affect. Postpartum $Napn_{acti}$ explained 25% of the variance in postpartum $DASS_{total}$ and about 21% in NA, with more naps associated with higher reported distress. However this prediction was no longer significant when somatic symptoms of anxiety and stress were excluded by the use of the HADS scores. The majority of postpartum mood scales (except for $DASS_{total}$, $DASS_{anxiety}$, and $DASS_{depression}$) were significantly associated with postpartum $Dysfunction_{psqi}$, suggesting that women's perceived interference of poor sleep on daytime function contributed to their mood states: higher sleep related dysfunction was associated with greater psychological distress. Third trimester $Dysfunction_{psqi}$ also to some extent contributed to women's postpartum mood as indicated in its significant association with postpartum $HADS_{total}$, $HADS_{anxiety}$, and PA.

Role of nighttime labor

Among participants who completed the questionnaires at both Time-1 and Time-2, 20 delivered their babies during the day, and 17 delivered at night. To test whether acute sleep deprivation associated with a nighttime labor increases the experience of mood disturbances immediately after delivery, a series of analyses of covariance were performed on postpartum mood between nighttime and daytime labor groups, with corresponding third trimester mood variables controlled as covariates. No significant difference in postpartum mood was found between women who had daytime and nighttime labors. This suggests that in this study, nighttime labor did not increase the report of mood disturbances at one week postpartum.

DISCUSSION

Changes in Sleep and Mood

This study confirmed previous findings that self-reported sleep is significantly worse during late pregnancy than non-pregnancy baseline. Although data were collected for the duration of one week, it is likely to reflect a persistent sleep disruption participants experienced during the third trimester.

Nearly half of the sample who delivered at night experienced total sleep deprivation on the night of labor; others were subjected to partial to full sleep deprivation on the first postpartum night, even though they delivered during the day. All participants experienced some degree of partial sleep deprivation over the nights after giving birth. Consistent with previous findings, nighttime sleep during the first postpartum week was significantly worse on the majority of objective and subjective measures when compared to that of the third trimester. Therefore by the end of the first postpartum week, participants were probably affected by persistent sleep disruption and sleep fragmentation accumulated throughout pregnancy as well as acute total/partial sleep deprivation related to birthing, a harsh mixture of most types of sleep disruptions.

In this study, average subjective and actigraphy TST and SE were similar, yet they did not correlate significantly at either Time-1 or Time-2; these findings are consistent with other studies reporting similarly low correlation coefficients between subjectively and actigraphically measured TST and SE.[39] This suggests that impressionistic estimations of sleep quality and quantity over a number of nights might reflect global changes in sleep but are not necessarily accurate measurements of actual sleep.

While most previous studies have focused only on women's nighttime sleep, this study also took into account participants' daytime napping behavior. Results largely confirmed that as women's nighttime sleep deteriorated, they took more naps during the day.[40] The increase in women's napping behavior coincided with a trend for increased report of sleep related daytime dysfunction, suggesting that daytime naps might reflect participants' conscious awareness of the impact of poor sleep on daytime functioning; this awareness is closely associated with their subjective perception of nighttime sleep.

Immediately after delivery, participants' mood improved on average rather than deteriorated. It is unlikely that acute sleep deprivation immediately after delivery played a role, as studies have consistently shown that the antidepressant effect of acute sleep deprivation is reversed as soon as the sleep deprived person obtains even a brief nap.[41,42] The general improvement of mood postpartum is consistent with a recent community prevalence study[43] showing that depression and anxiety symptoms might be even more prominent *during* pregnancy than *after*. Positive feelings about the newborn and the birthing experience might also have contributed to this improvement. Nevertheless, nearly half of the women in the sample were identified to have some deterioration of mood. Although this does not represent a diagnosis of postpartum blues, identified women might have experienced blues-like symptoms given the timing of their mood changes.

Mood and Sleep

In this study, evidence supporting a relationship between objective nighttime sleep and mood was present but weak. Lower positive affect at postpartum was related to poorer overall objective sleep during *the third trimester*. Even though lower positive affect is not equivalent to higher emotional distress, this effect is consistent with the depressogenic effect of long-term sleep disruption reviewed earlier. It could also be that women who slept better during pregnancy received more restorative benefits of sleep and were therefore more resilient to drastic changes in sleep-wake schedules postpartum. In contrast to objective measures, our data support a strong association between poor subjective nighttime sleep and greater psychological disturbances both during and after pregnancy, consistent with other recent reports.[19,20]

As women's nighttime sleep worsened following delivery, their perceived sleep related daytime dysfunction and napping behavior became relevant to their mood changes: higher sleep related daytime dysfunctions and more frequent naps were shown to be associated with higher reported distress. This, along with the finding that combined nighttime and daytime sleep were similar at Time-1 and Time-2, suggested that catch-up naps might reflect women's conscious effort to make up for nighttime sleep loss, and that in this study, sleep obtained in a daytime nap did not provide the same restorative value as sleep obtained at night.

The strong relationship between postpartum napping and DASS, but not HADS scores suggests that after delivery, women might have taken more naps due to somatic symptoms of anxiety and stress, which might or might not be related to postpartum physical changes. Both third trimester and postpartum $Dysfunction_{psqi}$ were closely associated with postpartum HADS and PANAS, but not quite as closely with DASS; this suggests that cognitive symptoms of depression or anxiety might have contributed to women's perception of daytime dysfunction.

This study does not support Wilkie and Shapiro's (1992) finding that nighttime labor increases the report of mood disturbances immediately after delivery.

Limitations

A major limitation of this study was the high attrition rate of 36.37% for actigraphy data by the end of the first postpartum week, higher than the 24% reported by Signal et al.[40] Drop-out on questionnaire data was low (6.82%) given the longitudinal nature of the study. High attrition rates not only narrowed the selection of statistical methods by limiting sample sizes but might have also changed the overall characteristics of participants across times. Although women who dropped out of either

the questionnaire or the actigraphy parts of the study did not differ in social demographic characteristics, there might have been differences in their psychological make-up (e.g., personality, attributional and cognitive styles) that the current study did not assess. These differences might be susceptible to the "filtering" effect of the rather demanding study protocol. Participants who made the most contribution to the study results, i.e., those who provided input to *both* objective *and* subjective sleep data, were likely to be more resilient in their biological makeup and/or coping skills than those who did not complete the whole study, as well as those who were not willing to participate in the first place. Given the initial selection criteria of healthy, low-risk women, attrition further held back generalization of findings to a clinical, or even an unselected community sample.

There is a lack of data on participants' baseline sleep and mood prior to pregnancy in this study. Although all women rated their pre-pregnancy sleep retrospectively, it was an indirect estimation rather than a direct measurement. As sleep need and the response to sleep disruption/deprivation differ among individuals,[44,45] lack of a control group in baseline sleep variation might reduce statistical power when mood-sleep analyses are conducted. The same limitation applies to mood.

Because of the rather unlikely occurrence of postpartum depression or psychosis among a group of low-risk women, follow-up measurements were only carried out until one week postpartum. This did not allow an investigation into the course of postpartum mood disturbance or how it might progress into postpartum depression in some cases.

Implications

Although correlational approaches do not reveal whether it was poor sleep that led to low mood, or emotional distress that caused sleep complaints, the weak relationship between objective sleep and mood found in the current study suggest that a cognitive-behavioral approach[46,47] might be applicable to the understanding of sleep-mood interaction among the group of low-risk women included in this study. That is, given the same stressor (e.g., sleep disruption as a consequence of pregnancy and delivery), individuals differ in their subjective experiences: women with higher levels of psychological distress might judge their sleep to be poorer; perceived poor sleep at night might in return exacerbate subjective stress and frustration, thus creating a potentially vicious cycle.

Pregnancy-related sleep disruptions, such as physical discomfort, pain, nighttime labor, and the newborn's frequent demands for care, are inevitable in the process of becoming a mother. Data in this study demonstrate some resilience among healthy mothers in anticipation of expected disruptions to their sleep on an objective level. More attention is perhaps needed when addressing women's subjective experiences of sleep problems, which are likely more susceptible to guidance than the inevitable and uncontrollable aspects of sleep disruption itself. Cognitive-behavioral interventions that target sleep related maladaptive cognitions and unhelpful safety behaviors (e.g., long catch-up naps),[48,49] as well as promote accepting and non-judgmental attitudes[50] might be helpful in reducing the distress associated with unnecessary struggles to maintain "normal" sleeping routines in the face of the demands of incipient motherhood.

CONCLUSION

Using both objective and subjective measurements of sleep, the current study supports the notion that, from late pregnancy to early postpartum, women experience a harsh mixture of different sleep disruptions, including persistent sleep disruption and sleep fragmentation, acute sleep deprivation related to birthing, and disruptions to their daily routines. Compared to actual sleep quality or quantity, the perception of poor sleep and the conscious awareness of its impact during wake time, may play a more active role in the occurrence of mood disturbances in a group of healthy, low-risk women during the immediate postpartum period. This has significant implications for providing psychological support for all those women at a challenging time in their lives.

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