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Title: Mid-pregnancy and postpartum maternal mental health and infant sleep in the first year of life

Short title: Maternal mental health and infant sleep

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Abstract

Perinatal depression and anxiety are common and associated with sleep problems in the offspring. Depression and anxiety are commonly co-morbid, yet often studied independently. Our study used an integrative measure of anxiety and depressive symptoms to examine the associations of maternal mental health (mid-pregnancy and postnatal) with infant sleep during the first year of life. 797 mother-child dyads from the Growing Up in Singapore Towards healthy Outcome cohort study provided infant sleep data at 3, 6, 9 and 12 months of age, using the caregiver reported Brief Infant Sleep Questionnaire. Maternal mental health was assessed at 26-28 weeks gestation and 3 months postpartum using the Edinburgh Postnatal Depression Scale, Beck Depression Inventory and State-Trait Anxiety Inventory. Bifactor modelling with the individual questionnaire items produced a general affect factor score that provided an integrated measure of anxiety and depressive symptoms. Linear mixed models were used to model the sleep outcomes, with adjustment for maternal age, education, parity, ethnicity, sex of the child and maternal sleep quality concurrent with maternal mental health assessment. We found that poorer mid-pregnancy, but not postpartum, maternal mental health was associated with longer wake after sleep onset duration across the first year of life (β=49, 95% CI 13 to 85 mins). Poor maternal mental health during mid-pregnancy is linked to longer period of night awakening in the offspring during infancy. Interventions that aim to improve maternal antenatal mental health should examine infant sleep outcomes.

Keywords: anxiety, depression, infant sleep, wake after sleep onset, general affect, mood

Introduction

Depressive and anxiety symptoms are common during perinatal phase, with antenatal and postpartum depression estimated to be between 8 to 11% and 6 to 13% respectively (Waldie et al., 2015). Aside from clinical depression, a large proportion of women also suffer from sub-clinical depression during pregnancy (Meaney, 2018). A meta-analysis showed that 18.2% of women reported anxiety symptoms in the first trimester and the proportion increased to 24.6% by the third trimester (Dennis, Falah-Hassani, & Shiri, 2017). Perinatal maternal mental health is linked to behavioural and cognitive problems in the offspring (O'Connor, Heron, Glover, & Alspac Study, 2002; O'Connor, Heron, Golding, Glover, & Team, 2003) and mood disorders (Van den Bergh et al., 2017) later in life.

In previous studies that examined maternal depression and sleep in infants, both antenatal as well as postnatal maternal depression were associated with more sleep problems (O'Connor et al., 2007; Pinheiro et al., 2011), longer sleep latency (Morales-Munoz et al., 2018), reduced sleep efficiency (Armitage et al., 2009), more bedtime distress (Goldberg et al., 2013) and more frequent night awakenings in the offspring (Gress-Smith, Luecken, Lemery-Chalfant, & Howe, 2012; Halal et al., 2021). The few studies that examined antenatal anxiety on infant sleep had similar observations of longer sleep latency (Morales-Munoz et al., 2018) and more sleep problems (O'Connor et al., 2007) as a function of anxiety. Goldberg et al. showed that postnatal anxiety at 6 months is associated with more concurrent night sleep issues such as more frequent night awakenings, longer wake after sleep onset and longer duration of crying after night awakening while postnatal anxiety at 12 months is associated with greater concurrent bedtime distress (Goldberg et al., 2013).

Infant sleep plays an important role in child development, including cognition and physical growth (Tham, Schneider, & Broekman, 2017). Sleep problems during infancy have been shown to be associated with subsequent sleep problems during early childhood, which in turn are linked to behavioural (Zuckerman, Stevenson, & Bailey, 1987) and learning problems (Hill, Hogan, & Karmiloff-Smith, 2007).

Most existing studies focus on clinically depressed or anxious mothers, however neuroimaging studies as well as those of cognitive – emotional function in the offspring suggest that the influence of maternal anxiety or depression symptoms on offspring operates across a continuum and is not limited to mothers with clinical disorders (Meaney, 2018; Qiu et al., 2015). Current literature on maternal mental health and infant sleep tends to focus on maternal depression (Armitage et al., 2009; Field et al., 2007; O'Connor et al., 2007) even though perinatal anxiety is no less prevalent than depression (Fairbrother, Janssen, Antony, Tucker, & Young, 2016). Those studies that included both depressive and anxiety symptoms, analyzed them independently of one another (Cook et al., 2020; Morales-Munoz et al., 2018; O'Connor et al., 2007). In fact, anxiety and depression are commonly comorbid, highly correlated (Falah-Hassani, Shiri, & Dennis, 2017; Phua et al., 2020) and difficult to study independently of one another. Co-morbid conditions of anxiety and depression represents a more severe maternal mental health condition (Evans, Myers, & Monk, 2008) and may have stronger influence on child outcomes (O'Donnell & Meaney, 2017).

These concerns suggest that an integrative measure that reflects symptoms of anxiety and depression is potentially a better predictor of child outcomes. Our group previously derived factor scores using exploratory bifactor analysis on items of common psychiatric screening tools for depression and anxiety (Phua et al., 2017). Most items loaded on a general affect factor that reflects general psychopathology and distress (Caspi et al., 2014). Integrating items from multiple psychiatric screening tools should help capture a more comprehensive picture of mothers' mental health, as represented by symptoms of anxiety and depression. In this study we investigated the association between maternal mental health and offspring sleep over the first year of life in term babies. We hypothesized that offspring born to mothers with poorer maternal affective state will have shorter sleep duration, more frequent night awakenings and stay awake for longer duration after night-time sleep onset.

Methods

Study population

Pregnant women aged ≥18 years (n=1450) were recruited between June 2009 and September 2010 in their first trimester (<14 weeks gestation) from Kandang Kerbau Women's and Children's Hospital and National University Hospital, to take part in the Growing Up in Singapore Towards healthy Outcomes (GUSTO) birth cohort study (Soh et al., 2014). Exclusion criteria include women who were on chemotherapy or psychotropic medication or had type I diabetes mellitus. The offspring were delivered between November 2009 and May 2011. Only term children (gestational age ≥37 weeks) from singleton, naturally conceived pregnancies were included in our analyses (Figure 1). We excluded preterm babies in our analyses as they tend to exhibit different sleep patterns from term babies (Y. S. Huang, Paiva, Hsu, Kuo, & Guilleminault, 2014).

Maternal mental health

Maternal mental health data were collected during pregnancy at 26-28 weeks gestation and 3 months postpartum, using self-administered questionnaires: the Edinburgh Postnatal Depression Scale (EPDS), Beck Depression Inventory (BDI-II) and State-Trait Anxiety

Inventory (STAI) which have all been validated in antenatal and postpartum women (Gibson, McKenzie-McHarg, Shakespeare, Price, & Gray, 2009; Meades & Ayers, 2011). EPDS and STAI have only been validated in Singaporean women with high-risk pregnancies (Thiagayson et al., 2013). As previously described, responses to the individual items from EPDS, BDI and STAI were fitted into an exploratory bifactor model (Phua et al., 2017). Parallel analysis was used to determine the number of factors, where the eigenvalues were computed from 1000 randomly generated correlation matrices. Factors were kept in the model if the eigenvalues of the observed data exceed that of the corresponding eigenvalues in the parallel analysis.

With bifactor modelling, most of the items from the three questionnaires loaded on the general affect factor, which reflects the overarching general negative affective symptoms of the individual, while a group of items will load onto each specific factors. In short, each item of the three questionnaires loads onto both the general affect factor as well a specific sub-factor (Phua et al., 2017). This approach contrasts with traditional factor analysis where each item loads onto a single factor. Factor scores of the general and specific factors (e.g. self-loath, positive mood) were derived from the confirmatory bifactor model. As we were interested in the effect of general negative affective symptoms of mothers on offspring's sleep, only the general affect factor score was used for subsequent analyses. The general affect factor also accounted for the most variance compared to the other specific factors. Moreover, the factor determinacy (i.e. indicator of reliability) of all the other specific factors did not pass the threshold of 0.80, except for positive mood. A higher general affect factor score corresponds to poorer mental health. The standard deviation of the general affect factor score was 0.27 and 0.24 respectively during mid-pregnancy and 3 months postpartum (Table 1).

Sleep data

Information on the offspring's actual day and night sleep duration (i.e not time in bed), number of awakenings and duration of wake after sleep onset (WASO), i.e., wake duration after night sleep onset (in minutes) at ages 3, 6, 9 and 12 months were reported by caregivers, using the Brief Infant Sleep Questionnaire (BISQ) which has been validated for infant population against actigraphy and sleep diaries (Sadeh, 2004) and used previously in the local population (Mindell, Sadeh, Wiegand, How, & Goh, 2010). Total daily sleep duration was derived by adding the caregiver reported night and day sleep duration.

Maternal sleep quality was assessed at 26-28 weeks pregnancy and 3 months postpartum, using the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989), which has comparable psychometric properties in both pregnant and non-pregnant populations (Zhong, Gelaye, Sanchez, & Williams, 2015). A higher global score (range 0 to 21) reflects poorer sleep quality.

Other data collected

Demographic data, including maternal age, highest education attained and ethnicity, were collected by interviewer-administered questionnaire during enrolment. Sex and gestational age of child and parity information were extracted from medical records by trained midwives. Breastfeeding information was collected using interviewer administered questionnaire at 3 weeks, 3, 6, 9 and 12 months in the first year of life. Duration of any breastfeeding were categorized as <1month, 1 to <3 months, 3 to <6 months, 6 to <12 months and ≥12 months. This study was approved by both the National Health Care Group Domain Specific Review Board (reference D/09/021 and 2014/00414) and the Sing Health Centralized Institutional Review Board (reference 2009/280/D). Written, informed written consent was obtained from all participants.

Statistical analysis

Descriptive statistics of the mother-child dyads and sleep outcomes are presented as mean ± standard deviation and N (%) for continuous and categorical variables, respectively. Longitudinal changes in the magnitude of association between maternal mental health and infant sleep outcomes over the first year were analyzed using linear mixed-effects models. The covariance structure for each model was selected based on the Akaike Information Criterion (AIC). For models with sleep duration outcomes (i.e., day, night and total sleep duration), an unstructured covariance structure was used. Compound symmetry and 1^{st}-order autoregressive, AR(1) were used for number of night awakenings and WASO, respectively. A multiplicative interaction term for general affect score X age of the child was also included for all models to test for differences in effect across ages. The mixed model was adjusted for maternal age, maternal education, parity, maternal ethnicity and sex of the child (model 1). We included a model 2, which is model 1 with additional adjustment for the maternal sleep quality concurrent with mental health assessment. This is in view of correlation between poor maternal sleep, poor infant sleep and poor maternal mental health (Wilson, Lee, & Bei, 2019). Breastfeeding has been linked to longer duration of awakenings, higher likelihood of night awakenings (Galland, Taylor, Elder, & Herbison, 2012) as well as longer nocturnal sleep duration (Cohen Engler, Hadash, Shehadeh, & Pillar, 2012). At the same time, a recent review showed that perinatal depressive symptoms are negatively associated with breastfeeding exclusivity and duration (Butler, Young, & Tuthill, 2021). As such, we did additional sensitivity analyses adjusted for duration of any breastfeeding which may be a potential confounder. We also added sensitivity analysis adjusting for postpartum maternal sleep quality for the analysis of mid-pregnancy mental health and infant sleep, to minimise reporting bias due to the mother's own poor sleep quality (i.e. a mother with poor sleep and awake in the night may report more awakening or WASO of their child). The sensitivity analyses provide insight into the association between maternal mental health on infant sleep, independent of breastfeeding or postpartum maternal sleep quality. Multiple imputations of missing data (maternal education) were conducted using chained equations imputation (5 imputations). For sleep outcomes where model 2 became non-significant (compared to model 1), additional mediation was done using the PROCESS macro for SPSS (Hayes, 2012), where 10,000 bootstrapped samples were drawn with replacement from the dataset to estimate a sampling distribution for the indirect mediation pathway. All analyses were carried out using SPSS software, version 24.0 (IBM, Armonk, NY, USA).

Results

Participant characteristics

Mother-child dyads (n= 797) with term-born offspring and a general affect score for at least one time-point as well as longitudinal sleep data were included in this study (Fig 1). Missing data were either due to withdrawal from the cohort study or missed visits. Mother-child dyads not included in this analysis were comparable to those included, in terms of ethnicity, parity, postpartum mental health and sex distribution. Participating mothers (Table 1) had lower mid-pregnancy EPDS (7.3 ± 4.4 vs 8.0 ± 4.8, p=0.021) and STAI-total scores (70.5± 17.6 vs 73.8 ± 18.7, p=0.008) than non-participants. They were also older (30.7 ± 5.0 vs 29.8 ± 5.5 years, p=0.002) and more likely to have attained university or higher education (36.1% vs 23.6%, p<0.001). Offspring participants had higher gestational age at birth (39.1 ± 1.0 vs 37.8 ± 2.3 weeks, p<0.001) and were more likely to be breastfed for 6 months or longer (38.7% vs 28.2%, p<0.001).

Maternal mental health and infant sleep

Offspring sleep outcomes in the first year are summarised in Table 2. Higher mid-pregnancy and 3-month postpartum general affect scores were both associated with longer WASO throughout the first year of life (Table 3, model 1), but the finding with 3 months postpartum general affect scores was attenuated, after adjusting for maternal sleep quality (model 2). Poorer maternal mid-pregnancy and 3 months postpartum sleep quality were associated with shorter night and total sleep duration as well as longer WASO (Supplementary Table 1) during infancy. Additionally, poorer maternal 3 months postpartum sleep quality was associated with increased night awakenings (Supplementary Table 1). There was no significant general affect score X age of the child interaction for any sleep outcome (data not shown). Mid-pregnancy maternal general affect score was associated with shorter total daily sleep duration in the first year of life (Table 3, model 1), but this association was also attenuated in model 2No other significant findings were observed with day and night sleep durations or number of night awakenings.

Sensitivity analyses with adjustment for duration of breastfeeding yielded similar findings for WASO across the first year [β= 55 (95% CI 19 to 91) min and β= 40 (95% CI -0.3 to 81) min respectively for mid-pregnancy and 3-months postpartum]. Additional adjustment for postpartum maternal sleep quality did not alter the significant positive association between mid-pregnancy maternal general affect and WASO [β= 65 (95% CI 23 to 106) min]. All other sleep outcomes remain non-significant. Sensitivity analyses with imputed data for missing maternal education yielded findings very similar to those limited to subjects with complete data on all covariates for model 1 (data available on request).

Mediation by maternal sleep quality between maternal mental health and infant sleep

Maternal antenatal sleep quality was a significant mediator between mid-pregnancy general affect and total sleep duration at 3 months [indirect effects: β=-0.86 (95% CI -1.59 to -0.20)].

However, maternal postpartum sleep quality is not a significant mediator between 3 months postpartum general affect and WASO at 3 months [indirect effects: β=12.27 (95% CI -5.86 to 30.22)].

Comparison of integrated general affect score with other mental health measurements

Supplementary Table 2 shows associations between each mental health measurements and the various infant sleep outcomes. During pregnancy, the integrated measure of general affect reported greater effect size on WASO compared to the other individual measures of mental health. The integrated measure and BDI were inversely associated with total and night sleep duration respectively. Additionally, higher antenatal EPDS scores were associated with increased awakenings. Postpartum, individual measures of mental health yielded greater effect size on WASO than the integrated measure. Higher postpartum BDI and STAI scores were also additionally associated with increased awakenings.

Discussion

An important and novel feature of our study is the use of an integrative measure derived from several questionnaires that measure anxiety and depression symptoms to get a more holistic representation of maternal mental health. To the best of our knowledge, our study is the first to use an integrated measure of mental health to study the association between maternal mental health and longitudinal caregiver reported infant sleep across first year of life. We found that poor mid-pregnancy maternal mental health (i.e., a high general affect score) was associated with longer WASO in the offspring, throughout infancy. Longer WASO in the first year was also observed in offspring of mothers with poor mental health at 3 months postpartum, but this was attenuated when the mother's postpartum sleep quality was taken into consideration. Shorter total sleep duration was observed in offspring of mothers with poor mental health during mid-pregnancy, but this was attenuated when adjusted for mother's antenatal sleep quality. We also found that antenatal sleep quality is a mediator between maternal antenatal mental health and total sleep duration in the offspring during infancy. No other significant association was found with other sleep parameters.

Several studies have analyzed associations between maternal anxiety and/or depression and offspring sleep duration during infancy and early childhood. In general, these studies reported no meaningful difference in total sleep duration in offspring of mothers who were anxious or depressed versus those who were neither anxious nor depressed (Armitage et al., 2009; O'Connor et al., 2007). Armitage *et al.* observed longer night sleep duration in low-risk infants born to non-depressed mothers compared to infants born to depressed mothers (Armitage et al., 2009). Other studies reported increased night awakenings in offspring born to mothers who were depressed and/or anxious, either during the preconception,(Baird, Hill, Kendrick, Inskip, & Group, 2009) antenatal (Armitage et al., 2009; O'Connor et al., 2007) or postpartum periods (Gress-Smith et al., 2012). Halal et al. showed that mothers with perinatal depression were more likely to report their 1-year-old infants to have >3 night awakenings per night but actigraphy data of the same infants showed no significant differences in night awakenings (Halal et al., 2021). We did not observe significant findings with caregiver reported infant sleep durations and number of nocturnal awakenings, possibly because we studied maternal mental health as a continuum of anxiety and depression symptoms and not just comparing the mothers with clinical or more severe levels of depression and/or anxiety symptoms with low-risk mothers. Moreover, we used a combination of instruments that measured anxiety and depression to derive an integrated measure of maternal mental health, instead of scores from any one of the instruments.

Cultural differences between studies in predominantly Caucasian and Asian populations may also have contributed to differences in results as all the literature cited above only studied

Caucasian infants. Many studies have observed significant differences between Caucasian and Asian infants, not just in terms of sleep duration but also sleep practices (Field, 2017; Galland et al., 2012; Mindell et al., 2010). Asian infants tend to have shorter total sleep duration, with later bedtimes and more co-sleeping and room sharing with the parents. The latter may also affect the accuracy of parental reports, the most common mode of data collection.

Our study is one of the few that reported caregiver reported WASO in infants in relation to maternal mental health and to the best of our knowledge, the first to incorporate maternal anxiety symptoms. Karraker et al. showed in a cross-sectional study, that the maternal depressive symptoms were positively associated with night wake time in 6 months old infants (Karraker & Young, 2007). In another smaller study, offspring of clinically depressed mothers had longer wake time at birth and 6 months of age, as measured by polysomnography (Bat-Pitault et al., 2017). These findings are consistent with ours where we also observed longer WASO with greater antenatal general affect symptoms. Longer WASO may indicate difficulty in settling back to sleep and may be an indication of poor sleep quality. Greater WASO during infancy has been linked to poorer memory working memory (Pisch, Wiesemann, & Karmiloff-Smith, 2019).

It is noteworthy that we saw a significant association with mid-pregnancy maternal mental health, but not postpartum maternal mental health. This finding could be attributed to the differential mechanisms by which they can influence infant sleep. *In utero* exposure to poor maternal mental health is likely to have programming effect on the fetus and subsequent behaviors (Field, 2011; O'Connor et al., 2007) that can affect sleep. For example, Kim et al. demonstrated that infant temperament may be a mediator between antenatal depression and more frequent nocturnal awakenings (Kim et al., 2020). Postnatal maternal mental health may affect infant sleep due to poor parenting, poor maternal sensitivity when interacting with their child (Murray, Stanley, Hooper, King, & Fiori-Cowley, 1996) and a reduced practise of good health habits and sleep routines (Minkovitz et al., 2005).

The effect of antenatal maternal mental health on neurodevelopmental outcomes in the offspring including sleep, may operate through many different pathways (O'Donnell & Meaney, 2017). One likely mechanism is the alteration of the hypothalamic-pituitary-adrenal (HPA) axis (Field, 2011), which can affect diurnal patterns, wakefulness and sleep (O'Connor et al., 2007). Postnatal maternal mental health may affect infant sleep due to impaired parenting, less maternal sensitivity when interacting with their child (Murray et al., 1996) and less likelihood to practise good health habits and sleep routines (Minkovitz et al., 2005). Our mediation analyses also suggest that one of the mediating pathways could be through the mother's own sleep quality. Sleep and mood have a bidirectional relationship, such that women with depressive symptoms tend to have more disrupted sleep (Goyal, Gay, & Lee, 2007) and women with poor sleep quality are more likely to be depressed (Tham et al., 2016). In turn, antenatal maternal sleep has previously been reported to be associated with infant sleep (Y. J. Huang et al., 2019; Nakahara et al., 2020).

Strengths of our study include its prospective longitudinal design, coupled with the repeated-measure mixed model analysis for sleep outcomes measured every three months throughout first year. Most studies are either cross-sectional or are limited by few and scattered prospective outcome measurements. Unlike many studies that focused on clinically depressed or anxious women, we studied a continuum of anxiety and depression symptoms using a integrated general affect score. Recent studies suggest that the influence of maternal anxiety or depression symptoms on offspring operates across a continuum and is not limited to mothers with clinical disorders (Meaney, 2018; Qiu et al., 2015). Our study included women with subclinical anxiety and/or depression and showed that suboptimal mental health indeed has implications for their offspring's sleep. The integrated measure comprehensively included anxiety and depressive symptoms, which tend to be comorbid (Falah-Hassani et al., 2017; Phua et al., 2020) and its performance is comparable, if not more robust, compared to other individual mental health assessments during pregnancy. We acknowledge that in postpartum period, the individual mental health assessments may be more predictive than the integrated measure, but the downside remains that each instrument only captures anxiety or depressive symptoms but not both.

Limitations of our study include the use of caregiver-reported questionnaires to collect data on infant sleep outcomes, which are subjective and susceptible to recall bias. This is especially true if the sleep outcomes were reported by the mother as her responses may be influenced by her own mental health. Previous studies suggest that parent-reported sleep parameters such as night awakenings and night sleep duration using the BISQ are predictive of later clinical sleep problems (Sadeh, 2004). Validation using objective measurements of sleep, such as actigraphy, would be helpful. We also acknowledge the potential bidirectional association between postnatal maternal mental health and infant sleep problems. Infants with sleep difficulties may cause maternal distress and in turn affect her mental health, but Teti et al. has shown that there is stronger evidence suggesting that it is maternal driven (Teti & Crosby, 2012).

As many factors can influence infant sleep, including biological, environmental, cultural and social factors, it is important to recognise that infant sleep problems may be inherent in factors not related to maternal mental health. We acknowledge that maternal distress may arise due to lack of sleep, such as tending to a wakeful infant. We attempted to address this by adjusting for sleep quality at the concurrent timepoint when maternal mental health is assessed. This is important in addressing the self-reproach new mothers often express, in their inability to soothe and put their babies to sleep. It is beneficial to our understanding that some of the risk factors are potentially modifiable, particularly maternal mental health. Our findings suggest that poorer maternal mental health during mid-pregnancy is linked to longer WASO in the infants. Interventions that aim to improve maternal antenatal mental health should examine infant sleep outcomes.

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Data availability statement

The data underlying this article will be shared on reasonable request to the corresponding author.

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Table 1: Characteristics of participating mother and child dyads

Maternal characteristics	n	Mean ± SD / N (%)
Maternal age (years)	797	30.7 ± 5.0
Ethnicity,	797	
Chinese		456 (57.2)
Malay		206 (25.8)
Indian		135 (16.9)
Maternal highest education category,	797	
No education/ Primary		38 (4.8)
Secondary		191 (24.0)
Diploma/ Technical education		273 (34.3)
University and above		288 (36.1)
Missing		7 (0.9)
Mid-pregnancy [a] BDI	773	8.4 ± 6.2
Mid-pregnancy [a] EPDS	792	7.3 ± 4.4
Mid-pregnancy [a] STAI-total	766	70.5± 17.6
Mid-pregnancy [a] general affect factor score	795	-0.01 ± 0.27
3 months BDI	631	7.7 ± 7.0
3 months EPDS	630	6.4 ± 4.7
3 months STAI-total	611	70.0 ± 19.1
3 months general affect factor score	584	0.00 ± 0.24
Child characteristics		
Gestational age (weeks)	797	39.1± 1.0
Gender (male)	797	420 (52.7)
Duration of any breastfeeding	797	
<1 month		180 (22.6)
1 to <3 months		148 (18.6)
3 to <6 months		135 (16.9)
6 to <12 months		137 (17.2)
>12 months		171 (21.5)
Missing		26 (3.3)

[a]Measured at 26-28 weeks gestation. BDI-Beck Depression Inventory; EPDS- Edinburgh Postnatal Depression Scale; STAI – State-Trait Anxiety Inventory

Table 2. Summary of sleep outcomes in the first year of life.

Sleep Variables	Age (months)							
	3		6		9		12	
	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD
Day sleep duration (h)	558	4.2 ± 2.5	640	3.4 ± 1.9	476	3.0 ± 1.5	458	2.8 ± 1.3
Night sleep duration (h)	577	7.9 ± 2.2	646	8.5 ± 1.9	478	8.9 ± 1.6	459	9.0 ± 1.6
Total sleep duration (h)	558	12.1 ± 3.6	640	11.9 ± 2.7	476	11.9 ± 2.2	458	11.8 ± 1.9
WASO (mins)	463	86 ± 74	503	58 ± 64	391	50 ± 63	376	40 ± 57
No. of night awakenings	579	1.8 ± 0.9	646	1.7 ± 1.0	497	1.6 ± 1.0	462	1.4 ± 1.0

SD, standard deviation

Table 3. Associations of infant sleep outcomes over the first year of life with mid-pregnancy and 3-month postpartum maternal general affect score

	Mid-pregnancy						3-month postpartum					
	n	**Unadjusted B (95% CI)**	**n**	**Adjusted[a] B (95% CI)**	**n**	**Adjusted[b] B (95% CI)**	**n**	**Unadjusted B (95% CI)**	**n**	**Adjusted[a] B (95% CI)**	**n**	**Adjusted[b] B (95% CI)**
Day sleep duration (min)	789	-37(-83 to 11)	782	-39 (-86 to 8)	468	-13 (73 to 48)	581	-35 (-95 to 26)	576	-38 (-99 to 23)	384	26 (-95 to 43)
Night sleep duration (min)	795	-40 (-83 to 4)	788	-34 (-77 to 0.22)	473	-22 (-77 to 32)	584	-17 (-73 to 37)	579	-15 (-70 to 40)	386	13 (-50 to 77)
Total sleep duration (mins)	789	**-73 (-140 to -5)**	782	**-71 (-139 to -4)**	468	-39 (-124 to 46)	581	-45 (-133 to 44)	576	- 48 (-136 to 40)	384	6 (-108 to 97)
WASO (min)	720	**51 (22 to 80)**	713	**44 (15 to 73)**	439	**49 (13 to 85)**	537	**58 (22 to 93)**	532	**54 (19 to 89)**	369	32 (-8 to 72)
No. of night awakenings	789	0.3 (-0.1 to 0.6)	782	0.3 (-0.1 to 0.6)	472	0.3 (-0.2 to 0.7)	581	0.3 (-0.1 to 0.8)	576	0.4 (-0.1 to 0.8)	389	0.1 (-0.3 to 0.6)

[a] Model 1- adjusted for maternal age, maternal education, sex of child, parity and ethnicity.

[b] Model 2- model 1 with additional adjustment of maternal sleep quality concurrent with maternal mental health assessment.

WASO: wake after sleep onset

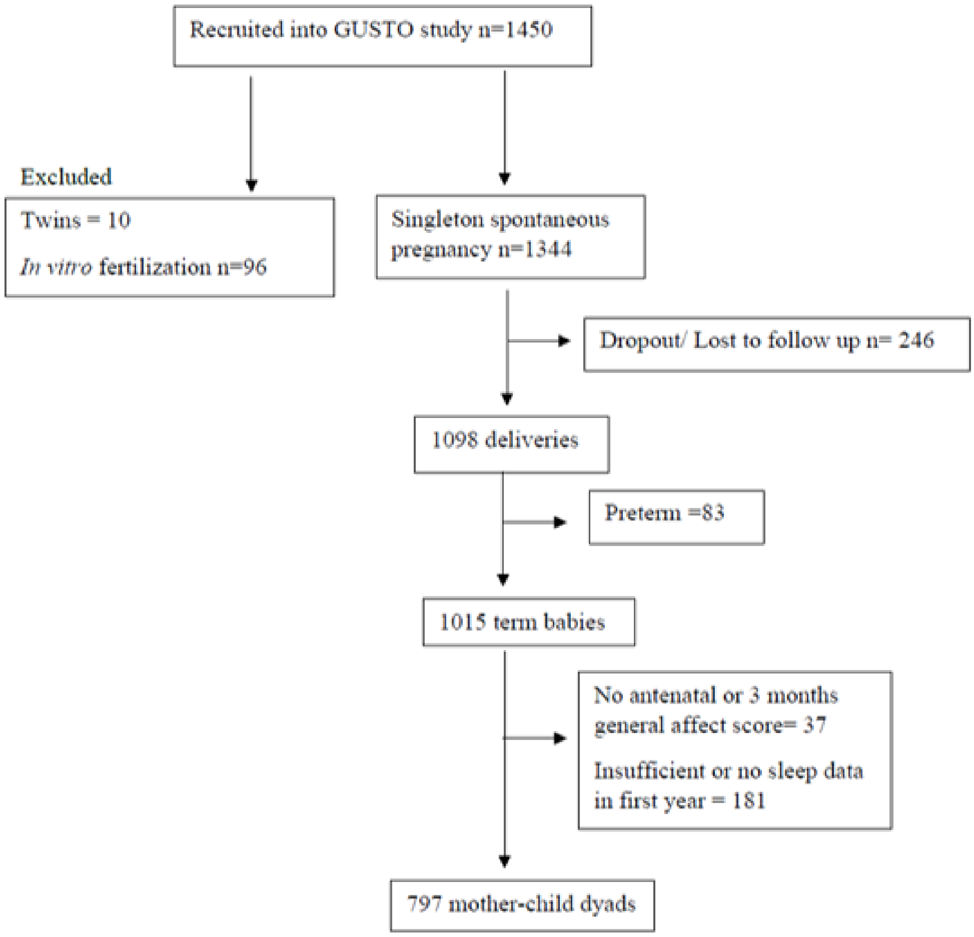

Figure 1. Flow chart describing participant inclusion for the current study.