Original Article

Trajectories of sleep quality from late pregnancy to 36 months postpartum and association with maternal mood disturbances: a longitudinal and prospective cohort study

Guanghai Wang1,2,†, Yujiao Deng1,2,†, Yanrui Jiang1,2, Qingmin Lin1,2, Shumei Dong1,2, Yuanjin Song1,2, Lixia Zhu1,2, Qi Zhu1,2, Wanqi Sun1,2,3, Yunting Zhang1,2 and Fan Jiang1,2,*

1Department of Developmental and Behavioral Pediatrics, Pediatric Translational Medicine Institution, Shanghai Children’s Medical Center, School of Medicine, Shanghai Jiaotong University, Shanghai, China, 2Ministry of Education–Shanghai Key Laboratory of Children’s Environmental Health, Shanghai, China, and 3Department of Psychology, Sleep Research Clinic and Laboratory, The University of Hong Kong, Pokfulam Road, Hong Kong, Hong Kong SAR

*Corresponding author. Fan Jiang, Department of Developmental and Behavioral Pediatrics, Shanghai Children’s Medical Center, School of Medicine, Shanghai Jiaotong University, 1678 Dongfang Road, Shanghai 200127, China. Email: fanjiang@shsmu.edu.cn.

†Guanghai Wang and Yujiao Deng share the first author.

Abstract

Study Objectives: To examine trajectories of poor sleep quality from late pregnancy to 36 months postpartum, baseline indicators, and association with prospective maternal mood disturbances.

Methods: A cohort of 262 nonclinical women was followed at late pregnancy, 42 days, 3, 6, 9, 12, 18, 24, and 36 months postpartum. Sleep quality was measured with the Pittsburgh Sleep Quality Index at all time points, and mood disturbances were assessed at late pregnancy and 36 months postpartum.

Results: The rate of poor sleep quality followed an inverted U-shaped curve. Women reporting poor sleep quality at late pregnancy held a consistently higher risk of poor sleep quality at postpartum points. Three sleep trajectories were distinguished, namely, the stable-low (29.4%), the decreasing–mild (56.5%), and the stable–high (14.1%). Poor sleep quality, depression, and anxiety at baseline were linked to trajectory groups with poorer sleep quality. Adjusting for covariates, the trajectory of the poorer sleep quality group demonstrated increased mood disturbances at 36 months postpartum. Replicating the analyses in women without baseline symptoms of depression and anxiety above clinical cutoffs obtained similar results.

Conclusions: Women are vulnerable to poor sleep quality from late pregnancy to postpartum years, but follow distinct trajectories. Poor sleep quality, depression, and anxiety at late pregnancy help us to anticipate the sleep trajectories. Trajectories of poor sleep quality indicate increased mood disturbances at 36 months postpartum. A flexible suite of interventions targeting both poor sleep quality and mood disturbances should be implemented and tailored to women in the prenatal and postpartum periods.

Statement of Significance

This study is the first to examine long-term trajectories of poor sleep quality from late pregnancy to early motherhood, and the prospective association with maternal mood disturbances. In 262 nonclinical women followed at late pregnancy, 42 days, 3, 6, 9, 12, 18, 24, and 36 months postpartum, three distinct trajectories of sleep quality were identified. Poor sleep quality and symptoms of depression and anxiety can help anticipate the sleep trajectories. A group with poorer sleep quality was linked to increased mood disturbances at 36 months postpartum. These findings indicate that prevention and treatment for poor sleep and associated mood disturbances in pregnancy and postpartum years should be prioritized.

Key Words: sleep quality; trajectories; pregnancy; postpartum; mood disturbances

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Introduction

Sleep is often at the bottom of a woman's priority list in our modern society. However, women are more susceptible to sleep disturbances than men [1]. The perinatal period with its myriad of physiological changes and psychological turmoil thrust vulnerable women into greater disturbed sleep. A deficit in sleep during the perinatal period should not be considered as "normal," whereas the adverse consequences of poor sleep have often been overlooked [2, 3]. Accumulating evidence suggests that imperative attention be given to women's sleep disturbances during pregnancy and the postpartum period due to the persistently high prevalence and pervasive detrimental effects on mother–child health. The estimated prevalence of poor sleep quality during pregnancy is on average 45.7%, ranging from 27.9% to 76% [4–7]. Poor sleep quality increases as pregnancy progresses [8], often persisting into the postpartum period, peaking during the first postpartum month, and remaining elevated afterwards [9]. Deficits in sleep during pregnancy have been linked to negative obstetric outcomes, including preterm birth [10–12], long labors, high risk of cesarean delivery [13, 14], increased gestational diabetes [7, 15], and poor health behaviors, such as binge eating [16]. In the postpartum period, sleep problems are associated with impaired neurobehavioral performance [17], poor quality of life, decreased daytime attentiveness [18], and disturbed sleep in infants [19, 20]. An additional concern related to disturbed sleep during pregnancy and the postpartum period is concurrent, recurrent, or/and prospective mood disturbances, particularly depression and anxiety [21–29]. Although there is contradictory evidence [30–32], these conditions can further impair maternal and fetal health [33], the quality caring [35], cause infant sleep and behavioral difficulties [36, 37], and even raise the risk for long-term adverse child outcomes [38]. However, previous studies were predominantly cross-sectional and confined to pregnancy and early postpartum, and evidence on the persistence of poor sleep quality into later life, and prospective association with disturbed moods is still lacking. Furthermore, filling the literature gap helps us to better inform treatment planning and management, and allows for early intervention to preempt or attenuate a full-blown episode.

Previous studies predominantly assumed pregnant women as a uniform population and assumed a mean sleep pattern in the perinatal period [8, 39]. The literature failed to distinguish subgroups who might follow distinct sleep trajectories. Nevertheless, it is of great ecological and clinical imperative to identify trajectory clusters for delivering targeted and tailored treatments, and shed additional light on the association between sleep and mood disturbances. So far, only a few studies have explored sleep trajectories in the perinatal period [23, 40–42] and call for more replications. In addition, it has been not fully addressed whether poor sleep in late pregnancy would continue beyond the first few months postpartum to later life, and what would be the distinct sleep trajectories, or how the trajectories would be prospectively associated with maternal mood disturbances in the postpartum years.

Determining baseline characteristics that can predict distinct sleep trajectory subgroups in the perinatal period is also critical for implementing prevention and intervention. Previous studies indicated several potential factors. Trajectories with poorer sleep quality from early pregnancy to 6 months postpartum evidenced increased sleep problems, and symptoms of depression and anxiety at the baseline [23]. Baseline sociodemographic characteristics such as maternal age, offspring's gender, BMI or weight gain during pregnancy, and socioeconomic status (SES) indexed by education and income level might implicate distinct sleep trajectories from pregnancy to postpartum years [23, 40, 41, 43], but the findings are conflicting and warrant further investigation.

Therefore, the current study followed 262 Chinese women at late pregnancy, 42 days, 3, 6, 9, 12, 18, 24, and 36 months postpartum to (1) identify distinct trajectories of maternal sleep quality, (2) determine whether poor sleep quality in late pregnancy can pose a risk of poor sleep quality in postpartum periods, (3) explore how sleep quality, depressive and anxiety symptoms, and several sociodemographic factors at baseline in late pregnancy can discriminate among sleep trajectories, and (4) examine the association between sleep trajectories and maternal mood status at 36 months postpartum.

Methods

Participants

Data were derived from the Child Health Promotion Project in Shanghai (CHPPS), which aimed to explore how the perinatal and early life environmental and behavioral factors affect early child growth and development in a longitudinal and prospective mother-child cohort. These mothers planned to live in Shanghai for at least 36 months since the recruitment, which allowed for follow-up. Pregnant women who were on chemotherapy, psychiatric drugs (including medications for depression or anxiety), or had gestational hypertension or diabetes mellitus were excluded from the study by screening the obstetric records. For the initial step, we identified 431 candidate women, but 262 women agreed to participate in our study. For the second phase, we carried out a person-to-person interview with the 262 mothers and double checked the obstetric records to endorse our inclusion and exclusion criteria. None of the mothers were excluded for delivering a neonate with intensive care unit hospitalization, or 1 and 5 min Apgar scores below 7, or reporting to have psychotropic drugs throughout the follow-up period. The mothers were all monogamous. We followed the mothers at 9 time points from June 2012 to August 2015, namely, late pregnancy (36–38 weeks of gestation), 42 days postpartum, and 3, 6, 9, 12, 18, 24, and 36 months after birth. There was a response rate for each time point of 81.3%, 87.74%, 85.32%, 77.73%, 70.04%, 61.9%, 61.69%, 69.87%, and 81.9% on the sleep quality measures, respectively. The dates of the analysis were September to December 2017. All participants signed informed consent, and the Shanghai Children’s Medical Center Human Ethics Committee (SCMCIRB-2012033) reviewed and approved this study.

Measures

Sleep quality

The Pittsburgh Sleep Quality Index (PSQI) was used to evaluate antenatal and postnatal maternal sleep quality at all survey points [44]. The PSQI total score represents the sum of component scores for subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleep...
medicine, and daytime dysfunction. A PSQI score of >5 indicates poor sleep quality. Higher scores indicate lower sleep quality or more severe sleep disturbance. The reliability and validation of the Chinese version of the PSQI has been satisfactorily established [7, 45]. In our study, Cronbach’s alphas for PSQI domains ranged from 0.63 to 0.75.

Antenatal emotional status

The Chinese version of Center for Epidemiological Survey-Depression Scale (CESD) was used to evaluate antenatal maternal depression symptoms [46, 47]. This scale consists of 20 items that measure the cognitive, affective, behavioral, and somatic symptoms associated with depression in the past week. Higher scores indicate greater overall depressive symptomatology and a score of 16 or more has been established as a standard cutoff indicative of risks for clinical depression. The Cronbach alpha in this study was 0.82.

As for the mother’s anxiety status, the Chinese version of State-Trait Anxiety Index (STAI) was used at baseline [27, 48]. A cutoff score of 40 at both state-anxiety index (S-AI) and trait-anxiety index (T-AI) indicates a significant anxiety level. The Cronbach alpha coefficient for the S-AI and T-AI in the current sample was 0.90 and 0.87, respectively. The CESD and STAI were used concurrently with PSQI in the late pregnancy.

Postnatal emotional status

Postnatal emotional symptoms were assessed at 36 months postpartum using the Profile of Mood States (POMS) [49]. The questionnaire measures six domains of mood states, including five negative ratings (tension–anxiety, anger–hostility, fatigue–inertia, confusion–bewilderment, and depression–dejection) and one positive rating (vigor–activity). Respondents were instructed to rate 65 adjectives on a scale of 0 = not at all to 4 = extremely, based on how they felt during the previous week. Higher scores indicate more negative mood state, except for vigor-activity for which lower scores denote negative mood state. The POMS was used concurrently with PSQI at 36 months postpartum.

Other variables

Maternal age, family income, and education were self-reported at baseline late pregnancy. The delivery age was 29.37 ± 3.21. Of the mothers, 90.2% had a bachelor degree and 33.2% had a family income above 200,000 RMB per year. Maternal BMI was 26.33 ± 2.8 kg/m². Gestational Weight Gain (GWG) was calculated and grouped into low, normal, and excessive, according to the updated 2009 IOM guidelines [50]. Whenever needed, we used GWG as a baseline predictor or an adjustment variable as it proved to be highly correlated with BMI and linked to postpartum depression [51].

Statistical methods

Data were double-blinded entered and cleaned to reduce error or bias. Missing data patterns were explored using t-test and χ² test between missingness groups. A “missingness” indicator for PSQI scores at each time point was created, with “1” for missingness and “0” for not missing. Independent t-test and χ² test were conducted between missingness groups both on baseline and terminal variables. The rationale for the analysis was to determine whether the baseline and terminal characteristics varied from missingness groups. If no difference was found between groups, the missing data were considered as “Missing Completely at Random” (MCAR), and handled using listwise deletion for analyses wherever needed [52].

The incidence rate of poor sleep quality among baseline characteristics was analyzed using χ² test to characterize the sample. For our primary aim, group-based trajectory models (GBTM) were used to detect different trajectories of sleep quality with 9 waves of data throughout late pregnancy to 36 months postpartum, with the traj add-on in Stata version 14.1 [53, 54]. We specified a zero-inflated Poisson distribution because of countable dependent variables. Models with up to four groups were estimated. Cubic, quadratic, linear coefficients, and intercept were considered to fit the best models. Bayesian Information Criterion (BIC) scores with greater Bayesian Information Criterion (BIC) scores with greater suggest a good fit. The STATA traj procedure handles missing data using a maximum likelihood algorithm, which uses all available data. Mothers were classified into different trajectory groups according to the highest probabilities for group membership.

For our second aim, the risk ratio associated with the antenatal sleep complaints group was calculated at each follow-up time using the binary logistic regression adjusting for baseline sociodemographic and emotional status. For our third aim, baseline characteristic differences among sleep trajectories were examined with the Kruskal–Wallis test and one-way ANOVA tests. For our fourth aim, ANOVA was used to explore whether mood status at 36 months postpartum differed among the sleep trajectory groups. Adjusting for pregnant-disturbed emotion at baseline is necessary. Therefore, the analyses were replicated for mothers without baseline depression and anxiety above the clinical cutoffs. Statistical analyses were conducted using Stata 14.0 and SPSS 17.0, with statistical significance was set at p < 0.05 (two-tailed).

Results

Incidence rate of poor sleep quality

No difference was found in CES-D scores, STAI scores, maternal age, maternal BMI, maternal educational status, family income, and POMS scores between missingness groups at the corresponding measured time point. Therefore, we consider that the data are MCAR and can be handled using listwise deletion for analyses.

As shown in Table 1, the incidence rate of poor sleep quality in each wave from late pregnancy to 36 months postpartum was 43.2%, 75.1%, 48.8%, 49.2%, 41.6%, 34.6%, 37.3%, 31.7%, and 38.4%, respectively, and represented by an inverted U-shaped curve with a peak at 42 days postpartum followed with a mild-decreasing curve. Mothers bearing boys or those with an older delivery age were more likely to experience poor sleep quality, with significant differences at 3 months and 12 months after delivery. No significant difference existed among mothers with different SES indexed by either family income or maternal education. Lower GWG was linked to a higher incidence rate only at 3 months postpartum. Mothers with antenatal depression...
or anxiety above the clinical cutoffs were at higher risk of poor sleep quality at several follow-up time points.

Figure 1 presents the results of the binary logistic regression analysis, showing that mothers with poor sleep quality at baseline were at increased risk of poor sleep quality throughout 36 months postpartum, adjusting for maternal age, educational level, family income, GWG, offspring's gender, depression, and anxiety at baseline. When replicating the analysis only for mothers without baseline depression and anxiety above the clinical cutoffs, the risk of poor sleep quality in the postpartum period was still linked to antenatal sleep issues at a significantly higher rate (Supplementary Figure 1).

### Identifying sleep trajectory groups

The best fit model was selected based on the BIC values from one-group model (BIC = –4036.37), two-group model (BIC = –3851.3), three-group model (BIC = –3824.91), and four-group model (BIC = –3834.08). Finally, three groups were chosen to be the best fit model and cubic coefficients were removed for all analyses. The posterior probabilities were 0.88, 0.86, and 0.86, respectively.

As shown in Figure 2, three trajectories were identified to reflect the differences in sleep quality. The first group was defined as the "stable-low," and made up 29.4% of the mothers. This group consistently had a minimal level of poor sleep quality throughout the study course, indicating the persistence of poor sleep quality. The second group was labeled as "decreasing-mild" and constituted 56.5% of the mothers, with more than half having mild sleep problems during the antenatal and postnatal periods. This group started with somewhat elevated PSQI scores than the clinical cutoff of 5 and decreased slightly as pregnancy progressed, and then remained mildly elevated till 36 months postpartum. The third group was labeled as "stable-high"; they had clearly elevated PSQI scores throughout the study course, indicating the persistence of poor sleep quality. This group accounted for 14.1% of the mothers. When replicating the analysis in mothers without baseline depression and wash...
anxiety above cutoffs, similar-shaped trajectories were identified, with a marked difference in the decreasing-mild group, whose PSQI score decreased to a level below the cutoff of 5 at 12 months postpartum and thereafter (Supplementary Figure 2).

Table 2 presents differences in baseline characteristics among the trajectory groups. None of the sociodemographic factors, including maternal delivery age, maternal education level, family income, offspring’s gender, and gestational weight gain differed across sleep trajectory groups ($p > 0.05$ for all). In addition, the analysis showed that the trajectory groups with poorer sleep quality reported elevated sleep disturbance, and symptoms of depression and anxiety at baseline.

Sleep quality trajectory and postnatal mood states

Figure 3 depicts a comparison of mood states at 36 months postpartum among sleep trajectory groups. Of the mothers, 74% completed the POMS. The missing group on the POMS questionnaire shows no significant difference on sleep trajectory distribution. The stable-high sleep group scored higher in all domains of disturbed mood, followed by the decreasing-mild sleep group and the stable-low group. The stable-low group demonstrated significantly lower disturbed mood scores than the stable-high group when using pairwise comparisons. The difference between the decreasing-mild group and the stable-high group was only noted in the anger-hostility and confusion-bewilderment domains. When the analysis was replicated for women without baseline depression and anxiety above clinical cutoffs, similar results were found except that no significant differences were found in the depression-dejection domain (Supplementary Figure 3).

Discussion

This study demonstrated distinct trajectories of sleep quality in pregnant and postpartum women. Based on raw data, the rate of poor sleep quality was seen as an inverted U-shaped curve with a peak at 42 days postpartum (around 75%), remaining at a higher or equivalent level until 9 months postpartum, and fluctuating around 35% till 36 months postpartum. Further analysis identified three trajectories that can distinguish latent group variances in the long-term change of sleep quality, namely, the stable-low group (29.4%), decreasing-mild group (56.5%), and stable-high group (14.1%). The stable-low group and the stable-high group might represent two poles of susceptibility or trait-like factors predisposing women to poor sleep quality. On the contrary, the decreasing-mild group might reflect women whose sleep quality is resilient during pregnancy, delivery, and early motherhood. When replicating the analysis only for women without the baseline symptoms of depression and anxiety above clinical cutoffs, similar-shaped trajectory groups were noted with a marked difference in the decreasing-mild group. Therefore, the sleep trajectories, particularly the shape, might be largely independent of the baseline depression and anxiety symptoms. Consistent with this argument, one previous study showed that adjusting for maternal depression did not attenuate the predictive effect of previous maternal sleep problems on either insomnia or short
Future studies are warranted as poor sleep quality and mood disturbances are often closely associated during the perinatal period. Consistent with previously reported trajectories of sleep quality from early pregnancy to 6 months postpartum by Tomfohr et al. [23], our study suggests that the long-term change in sleep quality from late pregnancy to 36 months postpartum is not unitary. However, we did not identify a group of women who have worsening sleep quality, namely, the increasing high trajectory, as Tomfohr et al. did. This discrepancy indicates that women’s sleep quality is likely to follow four trajectories from early pregnancy to late pregnancy, but three trajectories from late pregnancy to postpartum years. This finding also highlights the imperative to identify the high-risk groups as a priority target for treatment.

Several factors at the baseline in late pregnancy are linked to distinct sleep trajectories, which indicate priority for implementing early prevention and intervention. None of the sociodemographic factors addressed in our study significantly differ among the sleep trajectory groups. Combined with previous mixed findings [23, 40–42], our study highlights the need for further investigation of the validity of using sociodemographic factors as early identifiers for disturbed sleep trajectories. Poor sleep quality in early pregnancy has been considered as a unique risk factor for worsening sleep problems throughout pregnancy and the postpartum period [23]. It is possible that mothers reporting poor sleep quality at late pregnancy were those whose sleep quality was chronically disturbed and remained at a relatively stable-high level of severity, or who went on to more serious sleep

### Table 2. Baseline difference between the three sleep trajectory groups

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Stable-low N = 77 (29.4%)</th>
<th>Decreasing-mild N = 148 (56.5%)</th>
<th>Stable-high N = 37 (14.1%)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal age, years, mean ± SD</td>
<td>29.03 ± 2.81</td>
<td>29.53 ± 3.38</td>
<td>30.17 ± 3.19</td>
<td>0.229*</td>
</tr>
<tr>
<td>Gestational weight gain, %</td>
<td></td>
<td></td>
<td></td>
<td>0.509†</td>
</tr>
<tr>
<td>Low weight gain</td>
<td>21.9%</td>
<td>21.7%</td>
<td>37.5%</td>
<td></td>
</tr>
<tr>
<td>Normal weight gain</td>
<td>56.2%</td>
<td>59.9%</td>
<td>40.6%</td>
<td></td>
</tr>
<tr>
<td>Excessive weight gain</td>
<td>19.9%</td>
<td>18.5%</td>
<td>19.9%</td>
<td></td>
</tr>
<tr>
<td>Gender of offspring, %</td>
<td></td>
<td></td>
<td></td>
<td>0.16†</td>
</tr>
<tr>
<td>Boy</td>
<td>50.7%</td>
<td>47.1%</td>
<td>65.6%</td>
<td></td>
</tr>
<tr>
<td>Girl</td>
<td>49.3%</td>
<td>62.9%</td>
<td>34.4%</td>
<td></td>
</tr>
<tr>
<td>Maternal education, %</td>
<td></td>
<td></td>
<td></td>
<td>0.06†</td>
</tr>
<tr>
<td>High school</td>
<td>5.5%</td>
<td>11.5%</td>
<td>6.3%</td>
<td></td>
</tr>
<tr>
<td>College</td>
<td>78.1%</td>
<td>74.5%</td>
<td>62.5%</td>
<td></td>
</tr>
<tr>
<td>Postgraduate or higher</td>
<td>16.4%</td>
<td>14%</td>
<td>31.3%</td>
<td></td>
</tr>
<tr>
<td>Maternal BMI</td>
<td>25.53 ± 2.87</td>
<td>26.37 ± 2.8</td>
<td>25.72 ± 2.7</td>
<td>0.39†</td>
</tr>
<tr>
<td>Family income, %</td>
<td></td>
<td></td>
<td></td>
<td>0.43†</td>
</tr>
<tr>
<td>&lt;140000 yuan</td>
<td>38.4%</td>
<td>40.1%</td>
<td>31.3%</td>
<td></td>
</tr>
<tr>
<td>140000-20000 yuan</td>
<td>21.9%</td>
<td>30.6%</td>
<td>31.3%</td>
<td></td>
</tr>
<tr>
<td>≥20000 yuan</td>
<td>39.7%</td>
<td>29.3%</td>
<td>37.5%</td>
<td></td>
</tr>
<tr>
<td>Prenatal PSQI scores, Mean ± SD</td>
<td>3.71 ± 1.48</td>
<td>5.94 ± 2.56</td>
<td>8.35 ± 2.35</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>CESD scores, mean ± SD</td>
<td>7.95 ± 4.72</td>
<td>11.37 ± 5.97</td>
<td>12.34 ± 6.06</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>S-AI scores, mean ± SD</td>
<td>26.44 ± 7.05</td>
<td>30.76 ± 8.1</td>
<td>29.6 ± 6.47</td>
<td>0.001*</td>
</tr>
<tr>
<td>T-AI scores, mean ± SD</td>
<td>28.57 ± 5.58</td>
<td>33.32 ± 7.57</td>
<td>34.4 ± 7.14</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

BMI = body mass index; PSQI = Pittsburgh Sleep Quality Index; CESD = Center for Epidemiological Survey-Depression Scale; S-AI = state-anxiety index; T-AI = trait-anxiety index.

*Data evaluated with ANOVA.
†Data evaluated with Kruskal–Wallis tests.

Figure 3. Difference on POMS scores at each domain among different trajectories of sleep quality for mothers.
problems through late pregnancy and the postpartum years. Our analysis also showed that mothers reporting poor sleep quality at baseline were persistently at increased risk of poor sleep quality at all postpartum points, adjusting for confounding factors, or excluding mothers with symptoms of depression and anxiety above the cutoffs. This finding again highlights poor sleep quality itself as an independent chronic condition that warrants intervention in pregnancy and the postpartum years. Furthermore, those women with poorer sleep quality were those who reported more severe symptoms of depression and anxiety at baseline. Therefore, baseline emotional distress can be considered as a robust indicator of sleep trajectory disturbance largely because it can distinguish the severity level with each sleep trajectory, in spite of the limited effect on the trajectory shape as mentioned before. Consistent with our finding, the earlier study investigating sleep quality trajectory from early pregnancy to 6 months postpartum linked trajectories with poorer sleep quality to higher symptoms of depression and anxiety at the baseline [23]. In addition, there was substantial evidence cross-sectionally and longitudinally of an association of sleep quality with depression and anxiety among women in pregnancy and the postpartum period. The relationship is likely bidirectional [40]. Therefore, it is reasonable to argue that women reporting high symptoms of depression and anxiety are predisposed to a trajectory with poorer sleep quality in the postpartum years. Our study findings support routinely screening, assessing, and intervening for sleep problems and emotional distress during pregnancy to prevent the development of more serious sleep problems or transition to a higher risk trajectory.

One novel finding of our study was that sleep trajectory groups were associated with multiple domains of mood disturbances at 36 months postpartum. Women on a trajectory with poorer sleep quality demonstrated more disturbed mood, including tension–anxiety, depression–dejection, anger–hostility, fatigue–inertia, and confusion–bewilderment. This finding might reflect the enduring or cumulative effect of poor sleep quality on the development of mood disturbances. Although a threshold of change in sleep quality that precipitates the new onset of mood disturbances requires further investigation, our study indicated that intervention for high-risk sleep groups would be a priority. Substantial evidence has linked poor sleep quality to later depression, anxiety, and even psychopathology in pregnancy or the early postpartum period [22, 24, 29]. Moreover, few studies showed that sleep trajectories with poorer sleep quality or decreased sleep duration are more susceptible to depression in perinatal stage [23, 40]. Our study with a longer follow-up period adds to this line of inquiry and indicates that the detrimental effect of poor sleep quality extends to multiple domains of mood disturbance beyond depression and anxiety, and to later years than the perinatal stage.

Although further investigation is warranted to reveal the psychophysiological mechanisms linking poor sleep quality to mood disturbances, the impact of the deficit in sleep on emotional regulation [55–57] and systemic inflammatory markers [58, 59] has been documented in the expression of depression. Furthermore, culture-specific practices of common cosleeping with infants and parenting involvement at bedtime [60, 63] may also play an important role in the development of poor sleep, mood disturbances, and their relationship in Chinese women during the postpartum years. This should be addressed in further studies.

Our findings indicate that prevention and treatment for poor sleep and associated mood disturbances in pregnancy and postpartum years should be prioritized. The public should be better educated about the importance of maternal sleep and emotion health, its warning signs, and the need for access to professional help. In well pregnancy and baby checkup visits, screening and assessing for maternal sleep problems and emotional disturbances are critical for initiating early identification and intervention. The success of primary care screening for and treatment of depression in pregnant and postpartum women could be readily translated into sleep problems and other mood disturbances [62]. Health policies are needed to promote and ensure the implementation of these interventions. Effective management of infant sleep and crying problems has proved to decrease maternal depression [63]. Interventions that selectively target maternal sleep problems and mood disturbances during pregnancy or postpartum periods are currently under development and have shown promising effectiveness, through sleep hygiene and bedroom environment improvements [64], cognitive behavioral therapy for insomnia [65], mindfulness-based cognitive therapy [66], and light therapy [67]. Further efforts are needed to develop less expensive, scalable internet-delivered cognitive, and behavioral interventions that could reach increased numbers of mothers with sleep problems and mood disturbances in pregnancy and postpartum periods [68, 69]. Medication should be used cautiously in pregnant or lactating women to improve maternal sleep and emotional well-being, considering the potential increased risks of autism spectrum disorders [70], and other conditions [71, 72].

Limitations and strengths
Several limitations should be noted. The sample comprised nonclinical and healthy women with relatively high SES in Shanghai, one of the most developed cities in China, and 94.5% of the cohort had a university degree or above. Also, the small sample size and low response rate at follow-up points may limit the generalizability of the findings. Therefore, further studies should replicate the current study findings in larger and broader populations. An important limitation of this study is the use of the PSQI. Although PSQI is a validated tool, researchers have indicated that it is more closely linked to a negative cognitive style rather than actual sleep [73]. Although subjective measures of sleep quality prove to be a stronger predictor of postpartum depression symptoms than objective measure [74, 75], we need further replication of this work with sleep diaries or objective measures of sleep. Moreover, this study is limited by use of self-reported emotional status, and diagnostic interviews would add validity to our findings. Finally, we failed to adjust for more variables that might affect the study results, such as maternal history of mood disturbances and poor sleep quality, medical conditions, infant feeding and sleep parameters, and temperament.

The study has several strengths. It presents the first prospective study to identify maternal sleep trajectories from late pregnancy into 36 months postpartum with intensive follow-up points. The sample selected from a general population of women delivering at a public hospital allows maximum generalizability of the findings. More importantly, the current study is a rare one that has captured unique trajectories of sleep quality, multiple
baseline indicators, and the association with mood disturbances at 36 months postpartum, using novel statistical techniques and taking several confounding factors into account.

Conclusions
In summary, in this intensive following-up cohort from late pregnancy to 36 months postpartum, we identified three distinct trajectories to depict the long-term change of maternal sleep quality. Baseline maternal sleep quality, depression, and anxiety were significant factors helping to discriminate the sleep trajectories. Additionally, the results indicate the trajectory groups that are at an increased risk of mood disturbances at 36 months postpartum. Implementation of screening, assessment, and treatment of disturbed sleep and mood in the perinatal period and early motherhood is emphasized to reduce persistence and detrimental consequences. Further studies should focus on the association between the sleep trajectory and fetal and child health, as well as benefits of optimizing the sleep trajectories on emotional well-being.

Supplementary Material
Supplementary material is available at SLEEP online.

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