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Original Article

Association between sleep disturbances during pregnancy and adverse perinatal outcomes

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Abstract: Objective: To describe the changes in sleep pattern throughout pregnancy and to evaluate the relationship between sleep and adverse perinatal outcomes. Methods: Pregnant women at Qianfoshan Hospital completed questionnaires regarding their sleep during each of the three trimesters. Additionally, a subset of participants engaged in objective sleep monitoring using actigraphy devices. In the perinatal period, the following data were collected: pregnancy complications; gestational age; mode of delivery; Apgar scores for the neonate; and birth weight. Results: The total night sleep time in the second trimester was about 15 minutes shorter than that in the first trimester (P=0.024), and about 31 minutes shorter in the third trimester than in the second trimester (P<0.001). The sleep efficiency in the second trimester was about 10.23% lower than in the first trimester (P<0.001), and the efficiency in the third trimester was about 5.16% lower than in the second trimester (P<0.001). The occurrence of pregnancy-induced hypertension (PIH) was associated with sleep duration (P=0.019), sleep efficiency (P<0.001) and PSQI scores (P<0.001) in the first trimester. Furthermore, the mode of delivery was also found to be associated with sleep duration (P=0.011), sleep efficiency (P<0.001) and PSQI scores (P<0.001) in the first trimester. Conclusion: With the development of the pregnancy process, the sleep situation gets worse. Pregnant women's sleep situation in the first trimester of pregnancy is associated with the occurrence of PIH and delivery mode.

Keywords: Pregnancy, sleep quality, actigraphy, gestational outcomes

Introduction

Adequate sleep is essential for maintaining normal body function and repairing both physical and cognitive functions. Especially for pregnant women, sleep quality not only impacts their physical and mental health but also the development of the fetus. However, pregnancy brings significant hormonal, physical, physiological, and behavioral changes, leading to prevalent sleep disorders among expectant mothers [1-3]. Research indicates that the incidence of sleep disorders ranges from 48% to 79% during the first trimester, escalating to as high as 90% in the final trimester, with severe clinical symptoms including obstructive sleep apnea (OSA), frequent nocturnal awakenings, mouth breathing, and daytime sleepiness [1, 3, 4]. Sleep disorders typically include snoring, an increased number of waking after sleep onset (WASO), longer sleep latency [5], sleep apnea [6], restless legs [7], drowsiness, and increased daytime napping [8]. As awareness of sleep problems increases among pregnant women, more attention is being given to how sleep disorders affect pregnancy outcomes.

Sleep disorders can increase the risk of complications in pregnant women and negatively impact pregnancy outcomes, such as premature delivery [9], delivery methods [10], and even fetal and newborn development [11]. Mu-

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ltiple studies have shown that snoring, newly occurring in pregnancy, is an independent risk factor for gestational hypertension and preeclampsia [12-14]. Other research has linked increases in gestational diabetes to sleep-disordered breathing (SDB) during pregnancy [15, 16]. Felder et al. found that gestational women with insomnia or SDB suffered a 33% higher risk of premature delivery [9]. Meanwhile, research from Kajeepeta et al. showed that sleep duration less than 6 hours increases the risk of placental abruption [17]. However, other researchers have claimed that the relationship between sleep problems and perinatal outcomes was insignificant [18-20].

Hence, there is still no definite conclusion about the influence of sleep disorders on pregnancy outcomes. To address this gap, we employed various questionnaires that assess sleep duration, sleep efficiency, and sleep quality. Additionally, we used actigraphy, an effective tool for recording objective sleep data, to study the sleep characteristics of pregnant women in different stages of gestation. Our aim is to analyze which specific periods of sleep correlate more significantly with pregnancy outcomes.

Methods

Study participants and design

Our study included a total of 366 pregnant women from the Obstetrics Department at Qianfoshan Hospital. Each participant underwent a face-to-face interview conducted by a professional physician to quantify the association between sleep quality and pregnancy outcomes. This research was approved by the Ethics Committee of Qianfoshan Hospital (2018-S0091). Criteria for inclusion and exclusion were established based on previous research methodologies [21-23].

Inclusion criteria: (1) age between 18 and 50 years; (2) singleton pregnancy <13 gestational weeks; (3) informed consent provided; and (4) complete clinical information available. Exclusion criteria: (1) failure to meet the requirements for completing the questionnaire; (2) multiple pregnancies; (3) pre-existing chronic diseases such as hypertension and diabetes mellitus prior to pregnancy; (4) long-term use of antidepressants or psychotropic medications; (5) regular night shifts or habitual sleep of less than 2 hours per day; and (6) history of fetal or neonatal death.

The enrolled pregnant women completed questionnaires in their first trimester, with follow-up questionnaires conducted in the second and third trimesters. Those completed questionnaires through all three trimesters were included in this study. Demographic and anthropometric data like ages, obstetric history, and body mass index (BMI) of the enrolled women were collected during the first face-to-face interview.

Measurement of maternal sleep parameters

Key sleep parameters assessed included sleep duration, sleep efficiency, and sleep quality [24, 25]. Sleep duration of pregnant women refers to the actual time spent sleeping, which is the time from falling asleep at night to waking up [25]. Following previous research guidelines, a minimum of two hours of sleep was required to categorize the sleep as deprived, but there was no set upper limit for the maximum hours of sleep per day [26]. Sleep efficiency is defined as the ratio of total sleep duration to that spent in bed, later referring to the time from lying down to getting up [27].

The Pittsburgh sleep quality index (PSQI) was used to assess maternal sleep quality [27]. This tool uses an 18-item questionnaire that covers 7 aspects of sleep, including sleep duration, sleep latency, sleep quality, sleep medication, sleep disturbance at night, daytime function, and sleep efficiency. Each item is scored on a scale of 0-3, with a total possible score of 21. Higher scores indicate poorer sleep quality. The Epworth Sleepiness Scale (ESS) was used to evaluate maternal excessive daytime sleepiness [28]. The scores were aggregated, and the higher scores reflect greater sleepiness. The International Restless Legs Syndrome Study Group (IRLSSG) in 2011 was used to diagnose restless leg syndrome (RLS) [29]. In the present study, women reporting RLS symptoms four or more times in a month were diagnosed as having RLS.

Actigraphy

All the pregnant women were requested to wear an actigraphy device (Actiwatch II, Phillips, USA)

on their nondominant wrist for 7 days during each pregnancy phase. However, just 11 women completed all three phases. Actigraphy provides a relatively objective way to measure various sleep parameters, including time in bed, total sleep time (TST), number of awakenings, average waking time, and sleep efficiency [30].

Sleep diary

Alongside actigraphy, participants also maintained daily sleep diaries for 7 days at each assessment point. The sleep diary data of each participant was utilized to cross-verify the actigraphy data. Adjustments to sleep intervals recorded by the actigraphy were made only if manual calculation errors were detected [31].

Measurement of maternal and neonatal outcomes

Our study collected medical information on all enrolled pregnant women and their infants, as per guidelines from prior research. Pregnancy-induced hypertension (PIH) and gestational diabetes mellitus (GDM) were regarded as the main pregnancy outcomes, while cesarean birth, preterm birth, and Apgar scores at 1 minute were regarded as the secondary outcomes [21, 25]. PIH and GDM were defined as positive based on the diagnosis during pregnancy [21]. The neonatal data obtained included cesarean birth, preterm birth (classified as births occurring before 37 weeks), and Apgar scores at 1 minute [21, 32].

Statistical analysis

SPSS (version 21.0) was used for data analysis. Continuous variables that followed a normal distribution were described as mean ± standard deviation (SD). A student's t-test was used for comparison between the two groups, whereas an ANOVA was used for multiple groups. Otherwise, median with 25th and 75th percentiles was used to express the continuous variables that did not satisfy the normal distribution. Comparisons between two groups utilized the independent sample t-test, while one-way ANOVA followed by a post hoc pairwise Bonferroni or Tukey test was used for multigroup comparisons. The number of cases and percentages were used to describe the categorical variables. Comparisons between groups were evaluated by the Chi-square test. A Pearson test was used to determine the correlation between two quantitative data sets if they met the normal distribution. $P<0.05$ was considered statistically significant.

Results

Participants

In total, 366 pregnant women were enrolled during the 1st trimester (gestational week at 8-12), while only 199 went through all three trimesters. However, during the course of the study, some participants were lost to follow-up: 3 moved to another city, 6 switched hospitals to await delivery, and 3 experienced an abortion or miscarriage. Therefore, 187 women and their newborns were included in the final analysis (**Figure 1**).

Sleep pattern alteration during pregnancy

Data on sleep patterns during each trimester of pregnancy are presented in **Table 1**. The sleep duration of the pregnant women in the three trimesters was 7.70±0.87, 7.45±0.92, and 6.94±0.93 hours, respectively. The sleep efficiency of the pregnant women in the three trimesters was 0.86±0.09, 0.76±0.15, and 0.70±0.14, respectively. The PSQI scores, which represent sleep quality, were 4.86±2.93, 4.44±2.43, and 5.93±2.62, respectively. Based on our observations, the total nighttime sleep time of pregnant women got shorter as the weeks of pregnancy increased, about 15 minutes shorter in the second trimester than in the first trimester ($P=0.024$), and about 31 minutes shorter in the third trimester than in the second trimester ($P<0.001$). The sleep efficiency in the second trimester was about 10.23% lower than in the first trimester ($P<0.001$), and the efficiency in the third trimester was about 5.16% lower than in the second trimester ($P<0.001$). However, sleep quality in the second trimester, represented by PSQI values, was better than in the second trimester ($P<0.001$) and third trimester ($P<0.001$). Meanwhile, the ESS in the first trimester was slightly higher than that in the second trimester ($P>0.05$) but significantly higher than that in third trimester ($P=0.04$). This means that pregnant women are more prone to sleepiness in the first trimester of pregnancy and have a better quality of sleep in the second trimester of pregnancy.

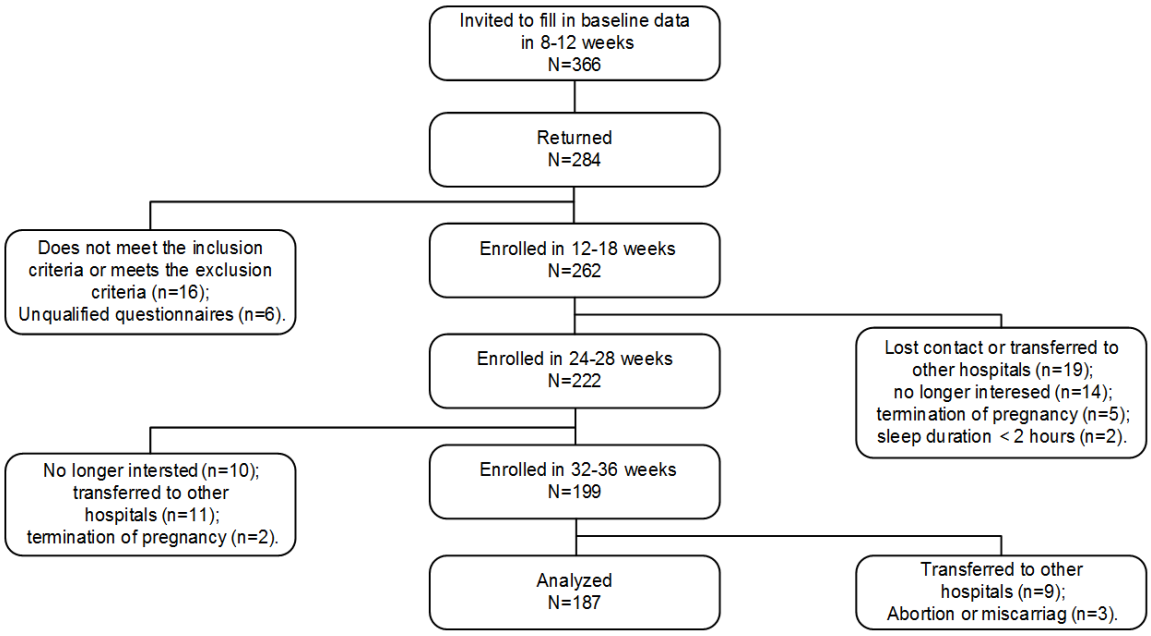

Figure 1. Flowchart of the recruitment process.

Table 1. The sleeping parameters across pregnancy

Characters	12-16 weeks (n=187)	24-28 weeks (n=187)	32-36 weeks (n=187)
Sleep duration	462.53±52^^^	447.75±55.2*	416.42±56##
Sleep efficiency	0.86±0.09^^^	0.76±0.15***	0.70±0.14###
PSQI total	4.86±2.93^^^	4.44±2.43	5.93±2.62###
ESS total	11.44±3.72^^	10.55±3.73	10.23±3.43
RLS ratio	16 (8.6)^	21 (11.2)	17 (9.1)

PSQI: Pittsburgh Sleep Quality Index; ESS: Epworth Sleepiness Score; RLS: restless leg syndrome. 12-16 weeks vs. 24-28 weeks, *P<0.05, ***P<0.001; 24-28 weeks vs. 32-36 weeks, ##P<0.01, ###P<0.001; 12-16 weeks vs. 32-36 weeks, ^P<0.05, ^^P<0.01, ^^^P<0.001.

Table 2. The objective sleeping parameters across pregnancy detected by actigraphy

Objective sleep	12-16 weeks (n=11)	24-28 weeks (n=11)	32-36 weeks (n=11)
Time in bed	532.63±48.50	480.63±39.58*	438.48±64.87^^^
Total sleep time	481.63±49.09	432.25±30.62	402.88±59.82^
WASO	51±15.31	48.17±21.63	36.27±15.06
Average waking time	1.8±0.35	2.31±0.35***	2.50±0.31^
Sleep efficiency (%)	90.37±3.02	90.09±4.11	91.97±3.45

WASO: wake time after sleep onset. 12-16 weeks vs. 24-28 weeks, *P<0.05, ***P<0.001; 12-16 weeks vs. 32-36 weeks, ^P<0.05, ^^^P<0.001.

Consistent with the description above, there were also significant changes on objective measurement of sleep assessed via actigraphy, including a reduction in TST in third trimester in comparison to first trimester (P=0.02), as well as a gradual increase in the number of awakenings (first vs. second trimester P< 0.001; first vs. third trimester P=0.04) (**Table 2**).

Pregnancy outcome

The demographic characteristics of the enrolled women are shown in **Table 3**. Among the participants, 14 (7.5%) developed pregnancy-induced hypertension (PIH), while 173 (92.5%) maintained normal blood pressure during gestation. The two groups did not differ in terms of age or reproductive history. However, there were significant group differences in BMI. For reproductive outcomes, 84 (44.9%) women had a cesarean section, while 103 (55.1%) had a vaginal delivery. The two groups did not differ in terms of age, BMI, or the history of reproduction. Meanwhile, there were 8 (4.3%) women with preterm delivery, and 179 (95.7%) deliv-

Table 3. Demographic characteristics of pregnant women with different gestational outcomes

Outcome	Age	BMI	Parity			History of cesarean section	
			0	1	2	No	Yes
PIH							
No (n=173)	29.72±4.20	22.59±2.83	116 (67.05)	56 (32.37)	1 (0.58)	146 (84.39)	27 (15.60)
Yes (n=14)	30.14±4.75	25.43±4.69	11 (78.57)	2 (14.29)	1 (7.14)	11 (78.57)	3 (21.43)
P	0.72	0.04*		0.04		0.37	
Delivery mode							
Vaginal delivery (n=103)	29.65±4.51	22.52±3.15	67 (52.76)	36 (62.07)	0 (0.00)	99 (96.12)	4 (3.88)
Cesarean (n=84)	29.94±3.82	23.11±2.99	60 (47.24)	22 (37.93)	2 (100.00)	58 (69.05)	26 (30.95)
P	0.64	0.20		0.14		0.11	
Delivery time							
Term (n=179)	29.72±4.23	22.78±3.12	120 (67.04)	57 (31.84)	2 (1.12)	154 (86.03)	25 (13.97)
Preterm (n=8)	31.13±3.48	22.88±2.17	7 (87.50)	1 (12.50)	0 (0.00)	3 (37.50)	5 (62.50)
P	0.36	0.93		0.48		0.003**	
Apgar scores							
10 (n=179)	29.73±4.22	22.76±3.11	120 (67.04)	57 (31.84)	2 (1.12)	154 (86.03)	25 (13.97)
<10 (n=8)	31.00±4.00	23.38±2.33	7 (87.50)	1 (12.50)	0 (0.00)	3 (37.50)	5 (62.50)
P	0.40	0.58		0.48		0.003**	

For complications in the pregnancy, there were significant group differences in BMI categories for the women who had PIH and those with normal blood pressure. There are significant differences of history of cesarean for the preterm and full term groups. There are significant differences of history of cesarean for the normal Apgar scores and low scores groups. *P<0.05, **P<0.01.

ered at term. The two groups did not differ in terms of age, BMI, or reproductive history, but significant differences were present in the history of cesarean delivery. For the fetal outcomes, there were 8 women (4.3%) who birthed newborns (preterm) with insufficient Apgar scores in 5 minutes, while 179 women birthed newborns with full Apgar scores. The two groups did not differ in terms of age, BMI, or reproductive history, although significant differences were noted in the history of cesarean delivery.

Tables 4-**6** show correlation matrixes of sleep and pregnancy outcomes across each trimester. Linear correlation models revealed significant associations between PIH and sleep duration (P=0.02), sleep efficiency (P<0.001) and PSQI (P<0.001) in the first trimester. Meanwhile, cesarean delivery was similarly associated with sleep duration (P=0.01), sleep efficiency (P<0.001) and PSQI (P<0.001) in the first trimester. Preterm also showed a correlation with PSQI scores (P=0.002). As the pregnancy progressed, despite deteriorating sleep duration and quality, the influence on PIH and cesarean delivery outcomes was not as marked as in the first trimester. Although sleep quality worsened in the second and third trimesters, no significant correlations were found with gestational hypertension or cesarean delivery during these periods.

Based on the above, we conducted a correlation analysis between sleep parameters and pregnancy outcomes, as detailed in **Tables 7**-**9**. The results showed that although sleep parameters differed among women with different pregnancy outcomes, adverse pregnancy outcomes (PIH, delivery mode) were associated with sleep duration, sleep efficiency, and PSQI scores only in the first trimester.

Discussion

Women undergo significant changes in cardiovascular, metabolic, immune, and respiratory systems during pregnancy, which can profoundly affect their sleep patterns [33-35].

Our results showed that, with the progression of pregnancy, the sleep duration got shorter and the sleep quality got worse. In the first trimester, pregnant women are lethargic and sleepy, and their sleep duration gets longer than before pregnancy [24, 36]. This aligns with previous studies that sleep duration decreased in the middle and late stages of pregnancy [24, 35]. This reduction in sleep can be attributed to

Table 4. Sleep characters during the first trimester of pregnancy (12-16 weeks) and gestational outcomes

Outcome	Sleep duration, mean ± SD	Sleep efficiency, mean ± SD	PSQI, mean ± SD	ESS, mean ± SD	RLS, N (%)
PIH					
No (n=173)	7.75±0.86	0.87±0.08	4.50±2.57	11.48±3.70	14 (8.09)
Yes (n=14)	7.18±0.93	0.75±0.11	9.29±3.56	11.00±4.13	2 (14.29)
P	0.02*	<0.001*	<0.001*	0.64	0.43
Delivery mode					
Vaginal (n=103)	7.82±0.94	0.88±0.09	3.62±2.75	11.53±3.83	11 (10.68)
Cesarean (n=84)	7.57±0.76	0.83±0.09	6.38±2.38	11.33±3.59	5 (5.95)
P	0.05	<0.001***	<0.001***	0.71	0.25
Time of delivery					
Term (n=179)	7.71±0.89	0.86±0.09	4.68±2.84	11.45±3.73	15 (8.38)
Preterm (n=8)	7.63±0.44	0.82±0.06	8.88±1.96	11.38±3.62	1 (12.50)
P	0.8	0.17	<0.001***	0.96	0.68
Apgar score in 5 minutes					
10 (n=179)	7.69±0.88	0.86±0.09	4.81±2.91	11.39±3.74	15 (8.38)
<10 (n=8)	8.00±0.60	0.85±0.05	6.00±3.30	12.75±3.11	1 (12.50)
P	0.33	0.91	0.26	0.31	0.68

*P<0.05, ***P<0.001.

Table 5. Sleep characters during second trimester of pregnancy (24-28 weeks) and gestational outcomes

Outcome	Sleep duration, mean ± SD	Sleep efficiency, mean ± SD	PSQI, mean ± SD	ESS, mean ± SD	RLS, n (%)
PIH					
No (n=173)	7.46±0.92	0.76±0.14	4.45±2.50	10.57±3.74	20 (11.56)
Yes (n=14)	7.43±0.90	0.74±0.17	4.43±1.40	10.36±3.75	1 (7.14)
P	0.92	0.66	0.97	0.84	0.61
Delivery mode					
Vaginal (n=103)	7.39±1.01	0.76±0.15	4.63±2.42	10.51±3.83	14 (13.59)
Cesarean (n=84)	7.54±0.79	0.76±0.14	4.21±2.44	10.60±3.63	7 (8.33)
P	0.26	0.95	0.24	0.88	0.26
Time of delivery					
Term (n=179)	7.46±0.93	0.76±0.15	4.46±2.43	10.53±3.76	20 (11.17)
Preterm (n=8)	7.38±0.69	0.73±0.15	4.13±2.53	11.00±3.16	1 (12.50)
P	0.81	0.66	0.71	0.73	0.91
Apgar in 5 minutes					
10 (n=179)	7.45±0.92	0.75±0.15	4.50±2.44	10.51±3.69	18 (10.06)
<10 (n=8)	7.54±0.82	0.82±0.12	3.13±1.89	11.50±4.78	3 (37.50)
P	0.79	0.22	0.12	0.46	0.02*

*P<0.05.

physical discomforts such as contractions, frequent urination, cramps, and Restless Legs Syndrome (RLS) [37]. A Finnish study reported that the average sleep duration at night was 8.2 hours in the first trimester, 8.0 hours in the second trimester, and 7.8 hours in the third trimester [24]. The average nighttime sleep duration of pregnant women in this study was 7.4±0.96 hours, lower than that in the Finnish study. We believe that the difference may be

Table 6. Sleep characters during the third trimester of pregnancy (32-36 weeks) and gestational outcomes

Outcome	Sleep duration, mean ± SD	Sleep efficiency, mean ± SD	PSQI, mean ± SD	ESS, mean ± SD	RLS, n (%)
PIH					
No (n=173)	6.93±0.95	0.70±0.13	5.98±2.66	10.26±3.34	17 (9.83)
Yes (n=14)	7.07±0.70	0.72±0.16	5.29±2.05	9.86±4.59	0 (0.00)
P	0.59	0.66	0.34	0.67	0.22
Delivery mode					
Vaginal (n=103)	6.92±1.02	0.70±0.14	5.69±2.77	10.42±3.37	10 (9.71)
Cesarean (n=84)	6.97±0.83	0.71±0.14	6.23±2.42	10.00±3.51	7 (8.33)
P	0.75	0.71	0.16	0.41	0.74
Time of delivery					
Term (n=179)	6.96±0.94	0.70±0.14	5.93±2.62	10.22±3.50	16 (8.94)
Preterm (n=8)	6.56±0.86	0.74±0.13	6.00±2.93	10.38±1.41	1 (12.50)
P	0.24	0.51	0.94	0.79	0.73
Apgar in 5 minutes					
10 (n=179)	6.95±0.95	0.70±0.14	5.91±2.61	10.20±3.45	16 (8.94)
<10 (n=8)	6.88±0.44	0.76±0.14	6.38±3.07	10.88±3.04	1 (12.50)
P	0.84	0.29	0.63	0.59	0.73

Table 7. Correlation analysis at the early stage of pregnancy (12-16 weeks)

Outcome	Sleep duration	Sleep efficiency	PSQI	ESS
PIH	-0.17*	-0.28***	0.34***	-0.04
Cesarean delivery	-0.19*	-0.31***	0.56***	-0.01
Preterm	-0.05	-0.14	0.28*	0
Apgar	0.08	-0.02	0.08	0.1

PIH and delivery mode are associated with sleep duration, sleep efficiency and PSQI scores in the first trimester. *P<0.05, ***P<0.001.

Table 8. Correlation analysis at the middle stage of pregnancy (24-28 weeks)

Outcome	Sleep duration	Sleep efficiency	PSQI	ESS
PIH	-0.01	-0.02	0.04	-0.03
Cesarean delivery	0.07	0	-0.1	0.05
Preterm	-0.02	-0.03	-0.02	0.04
Apga	0.01	0.09	-0.1	0.04

Pregnancy outcomes are not associated with sleep duration, sleep efficiency and PSQI scores in the middle trimester.

related to the habit of taking naps in China, which is rare in most Western countries [38, 39]. Daytime naps may shorten sleep duration at night.

Previous research indicated that most women in pregnancy experienced a decline in sleep quality [38]. More than 79% of women in the early stages of pregnancy experience weakened airway control due to increased uterine volume, diaphragm elevation, and a relative reduction in chest volume. The relative high levels of estrogen and progesterone during pregnancy can lead to snoring, or OSA [12, 33]. In addition, Wang et al. showed gestational women with poor sleep exhibited higher expression of inflammatory markers such as IL-10, CRP, and TNF-α, than those with good sleep [40]. Besides, emotional stress, dreams, and anxiety about significant lifestyle changes, also affect the sleep satisfaction among pregnant women [9, 41].

We found that pregnant women's sleep duration, sleep efficiency, and sleep quality are associated with pregnancy-induced hypertension, especially in the first trimester of pregnancy. This is consistent with previous studies indicating that pregnant women who slept less than six hours were more likely to develop high blood pressure during pregnancy [42, 43]. In

Table 9. Correlation analysis at the last stage of pregnancy (32-36 weeks)

Outcome	Sleep duration	Sleep efficiency	PSQI	ESS
PIH	0.05	0.03	-0.06	-0.07
Cesarean delivery	0.04	0.04	0.09	-0.09
Preterm	-0.09	0.05	0.01	0.06
Apgar	-0.02	0.08	0.03	0.06

Pregnancy outcomes are not associated with sleep duration, sleep efficiency and PSQI scores in the last trimester.

addition to this, hypoxemia and hypercapnia due to obstructed ventilation can cause sympathetic excitation, manifested by increased release of catecholamine, renin, and angiotensin, and elevated blood pressure [42]. Furthermore, reductions in sleep duration are associated with increased blood pressure. Yang and colleagues found a 10% increase in cardiovascular and all-cause mortality for each hour of reduced sleep [44]. Intermittent hypoxemia and sympathetic excitation caused by serious sleep disorders such as SDB may lead to or aggravate hypertension [12, 45]. Sleep apnea and hypopnea, conditions marked by repeated interruptions in breathing, lead to frequent instances of hypoxemia and hypercapnia. This persistent stress response increases the secretion of catecholamines, renin, and angiotensin, further contributing to high blood pressure [12, 45, 46].

While studies have been inconsistent in the effect of sleep on delivery patterns, recent findings increasingly suggest that poor sleep, including lethargy, insomnia, and sleep apnea, can be risk factors for unnatural labor [10]. A study from Taiwan observed a negative correlation between sleep duration and labor duration in women who underwent vaginal delivery; however, neither actigraphy-derived nor self-reported sleep variables were found to be associated with the type of delivery [47]. Our findings suggest sleep duration only in the first trimester (12-16 weeks) was positively correlated with the likelihood of a natural birth. This does not align with previous studies finding that frequent awakenings and sleep disruptions in the third trimester of pregnancy increase the risk of cesarean section [48]. This discrepancy could be attributed to various factors, including differences in study populations, methodologies, or definitions of what constitutes a sleep disturbance. Poor sleep quality can lead to physical fatigue, reducing a woman's endurance needed for vaginal delivery [49]. At the same time, anxiety, depression, and other negative emotions caused by sleep disorders aggravate maternal fear of vaginal delivery [50]. In addition, poor sleep quality is often combined with pregnancy-induced hypertension and other complications, which increase the medical necessity for a cesarean delivery [51, 52].

Emerging evidence indicates the relationship between sleep changes during pregnancy and birth outcomes, including premature birth and intrauterine growth restriction [11, 53, 54]. Consistent with that, our research indicates that pregnant women with higher PSQI during the first trimester is associated with preterm birth. The mechanism for the association between sleep quality in the early trimester and adverse birth outcomes is not clear. Okun and his colleges proposed that the sleep problems during the first 20 weeks of pregnancy may lead to increased systemic inflammation, which is necessary for early pregnancy success, but could also exacerbate inflammatory response that interferes with normal trophoblast invasion [54, 55]. The latter situation would result in subsequent disruption of the remodeling of the maternal vessels of the maternal vascular bed, contributing to preeclampsia, preterm birth, and intrauterine growth restriction [54, 55].

While our findings are provocative, we acknowledge that there are still some limitations. Firstly, owing to the small size of the samples, we could not thoroughly explore variations within different levels of sleep quality or duration. Furthermore, given the low number of adverse outcomes, we could not analyze the relationship between sleep and other fetal outcomes like preterm birth and low birth weight. Finally, our study was a mere observational study without intervention or treatment. In the future, we will further investigate whether positive sleep interventions during pregnancy will improve pregnant women's or fetal outcomes.

Despite these limitations, our study has several strengths that enhance the credibility and reliability of the findings. The longitudinal tracking

and collection of medical and sleep characteristics at various pregnancy stages provide a comprehensive view of how sleep changes over time and its potential impacts. In addition, the use of actigraphy to record and analyze sleep data adds an objective measure to our study, supporting the subjective reports from sleep questionnaires.

In summary, our findings provide new and more objective evidence of the association between poor sleep and adverse pregnancy outcomes. And for the first time, to indicate that the early trimester is a period in which sleep conditions are associated with poor pregnancy outcomes.

Disclosure of conflict of interest

None.

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References

[1] Moline M, Broch L and Zak R. Sleep problems across the life cycle in women. Curr Treat Options Neurol 2004; 6: 319-330.

[2] Reid J, Skomro R, Cotton D, Ward H, Olatunbosun F, Gjevre J and Guilleminault C. Pregnant women with gestational hypertension may have a high frequency of sleep disordered breathing. Sleep 2011; 34: 1033-1038.

[3] Saaresranta T and Polo O. Hormones and breathing. Chest 2002; 122: 2165-2182.

[4] Cai XH, Zhang HG, Xu XF, Xuan MY, Yu CY, Li ML, Xie YP, Wang YH, Fang XH and Lv JQ. An epidemiological study on the sleep disorders of pregnant women in Wenzhou, Zhejiang province. Zhonghua Liu Xing Bing Xue Za Zhi 2010; 31: 597-599.

[5] Okun ML, Kohl V and Feliciano L. Comparison of longitudinal diary and actigraphy-assessed sleep in pregnant women. Sleep Med 2021; 88: 149-156.

[6] Sedov ID, Cameron EE, Madigan S and Tomfohr-Madsen LM. Sleep quality during pregnancy: a meta-analysis. Sleep Med Rev 2018; 38: 168-176.

[7] Na M, Wu J, Li M, Hinkle SN, Zhang C and Gao X. New onset of restless legs syndrome in pregnancy in a prospective multiracial cohort: incidence and risk factors. Neurology 2020; 95: e3438-e3447.

[8] Tsai SY, Lee PL, Lin JW and Lee CN. Persistent and new-onset daytime sleepiness in pregnant women: a prospective observational cohort study. Int J Nurs Stud 2017; 66: 1-6.

[9] Mairesse J, Van Camp G, Gatta E, Marrocco J, Reynaert ML, Consolazione M, Morley-Fletcher S, Nicoletti F and Maccari S. Sleep in prenatally restraint stressed rats, a model of mixed anxiety-depressive disorder. Adv Neurobiol 2015; 10: 27-44.

[10] Howe LD, Signal TL, Paine SJ, Sweeney B, Priston M, Muller D, Lee K, Huthwaite M and Gander P. Self-reported sleep in late pregnancy in relation to birth size and fetal distress: the E Moe, Mama prospective cohort study. BMJ Open 2015; 5: e008910.

[11] Hajipour M, Soltani M, Safari-Faramani R, Khazaei S, Etemad K, Rahmani S, Valadbeigi T, Yaghoobi H and Rezaeian S. Maternal sleep and related pregnancy outcomes: a multicenter cross-sectional study in 11 provinces of Iran. J Family Reprod Health 2021; 15: 53-60.

[12] Truong KK and Guilleminault C. Sleep disordered breathing in pregnant women: maternal and fetal risk, treatment considerations, and future perspectives. Expert Rev Respir Med 2018; 12: 177-189.

[13] Perkins A and Einion A. Pregnant pause: should we screen for sleep disordered breathing in pregnancy? Breathe (Sheff) 2019; 15: 36-44.

[14] O'Brien LM, Bullough AS, Owusu JT, Tremblay KA, Brincat CA, Chames MC, Kalbfleisch JD and Chervin RD. Pregnancy-onset habitual snoring, gestational hypertension, and preeclampsia: prospective cohort study. Am J Obstet Gynecol 2012; 207: 487, e481-489.

[15] Qiu C, Lawrence W, Gelaye B, Stoner L, Frederick IO, Enquobahrie DA, Sorensen TK and Williams MA. Risk of glucose intolerance and gestational diabetes mellitus in relation to maternal habitual snoring during early pregnancy. PLoS One 2017; 12: e0184966.

[16] Izci-Balserak B and Pien GW. Sleep-disordered breathing and pregnancy: potential mechanisms and evidence for maternal and fetal morbidity. Curr Opin Pulm Med 2010; 16: 574-582.

[17] Kajeepeta S, Sanchez SE, Gelaye B, Qiu C, Barrios YV, Enquobahrie DA and Williams MA. Sleep duration, vital exhaustion, and odds of spontaneous preterm birth: a case-control study. BMC Pregnancy Childbirth 2014; 14: 337.

[18] Portaluppi F, Cortelli P, Buonaura GC, Smolensky MH and Fabbian F. Do restless legs syndrome (RLS) and periodic limb movements of sleep (PLMS) play a role in nocturnal hypertension and increased cardiovascular risk of re-

nally impaired patients? Chronobiol Int 2009; 26: 1206-1221.
[19] Chang JJ, Pien GW, Duntley SP and Macones GA. Sleep deprivation during pregnancy and maternal and fetal outcomes: is there a relationship? Sleep Med Rev 2010; 14: 107-114.
[20] Abedi P, Bagheri R, Qorbani M and Ansari S. Is there a relationship between restless legs syndrome and medical problems in pregnant women? A cross-sectional study in Iran. Acta Neurol Belg 2020; 120: 1091-1096.
[21] Oyieng'o DO, Kirwa K, Tong I, Martin S, Antonio Rojas-Suarez J and Bourjeily G. Restless legs symptoms and pregnancy and neonatal outcomes. Clin Ther 2016; 38: 256-264.
[22] Sharma SK, Nehra A, Sinha S, Soneja M, Sunesh K, Sreenivas V and Vedita D. Sleep disorders in pregnancy and their association with pregnancy outcomes: a prospective observational study. Sleep Breath 2016; 20: 87-93.
[23] Cai Y, Ma G and Fan J. Effects of sleep quality in early pregnancy on pregnancy outcomes and mood state. Sleep Breath 2024; 28: 1079-1087.
[24] Hedman C, Pohjasvaara T, Tolonen U, Suhonen-Malm AS and Myllylä VV. Effects of pregnancy on mothers' sleep. Sleep Med 2002; 3: 37-42.
[25] Kominiarek MA, Yeh C, Balmert LC, Facco F, Grobman W and Simon M. Sleep duration during pregnancy using an activity tracking device. AJP Rep 2020; 10: e309-e314.
[26] Xu X, Conomos MP, Manor O, Rohwer JE, Magis AT and Lovejoy JC. Habitual sleep duration and sleep duration variation are independently associated with body mass index. Int J Obes (Lond) 2018; 42: 794-800.
[27] Tang Y, Dai F, Razali NS, Tagore S, Chern BSM and Tan KH. Sleep quality and BMI in pregnancy- a prospective cohort study. BMC Pregnancy Childbirth 2022; 22: 72.
[28] Zhang CJ, Su YJ, Chen Y, Wang ZJ, Hu SL, Xu HH, Liu YP, Li XY, Zhu HM, Yi HL, Guan J, Teng YC and Yin S. Sleep quality and sleep disturbances in Chinese pregnant women: a multicenter cross-sectional study. Zhonghua Er Bi Yan Hou Tou Jing Wai Ke Za Zhi 2022; 57: 308-316.
[29] Mubeen SM and Ahsan MD. Prevalence and associated factors of restless leg syndrome (RLS) in Pakistani women during pregnancy. J Obstet Gynaecol 2022; 42: 1829-1834.
[30] Sahota PK, Jain SS and Dhand R. Sleep disorders in pregnancy. Curr Opin Pulm Med 2003; 9: 477-483.
[31] Carney CE, Buysse DJ, Ancoli-Israel S, Edinger JD, Krystal AD, Lichstein KL and Morin CM. The consensus sleep diary: standardizing prospective sleep self-monitoring. Sleep 2012; 35: 287-302.
[32] Peltonen H, Paavonen EJ, Saarenpää-Heikkilä O, Vahlberg T, Paunio T and Polo-Kantola P. Sleep disturbances and depressive and anxiety symptoms during pregnancy: associations with delivery and newborn health. Arch Gynecol Obstet 2023; 307: 715-728.
[33] Meers JM and Nowakowski S. Sleep during pregnancy. Curr Psychiatry Rep 2022; 24: 353-357.
[34] Rajagopal A and Sigua NL. Women and sleep. Am J Respir Crit Care Med 2018; 197: P19-P20.
[35] Delgado A and Louis JM. Sleep deficiency in pregnancy. Sleep Med Clin 2023; 18: 559-571.
[36] Bei B, Coo S, Baker FC and Trinder J. Sleep in women: a review. Aust Psychol 2015; 50: 14-24.
[37] Alonso-Fernández A, Ribot Quetglas C, Herranz Mochales A, Álvarez Ruiz De Larrinaga A, Sánchez Barón A, Rodríguez Rodríguez P, Gil Gómez AV, Pía Martínez C, Cubero Marín JP, Barceló Nicolau M, Cerdà Moncadas M, Codina Marcet M, De La Peña Bravo M, Barceló Bennasar A, Iglesias Coma A, Morell-Garcia D, Peña Zarza JA, Giménez Carrero MP, Durán Cantolla J, Marín Trigo JM, Piñas Cebrian MC, Soriano JB and García-Río F. Influence of obstructive sleep apnea on systemic inflammation in pregnancy. Front Med (Lausanne) 2021; 8: 674997.
[38] Sweet L, Arjyal S, Kuller JA and Dotters-Katz S. A review of sleep architecture and sleep changes during pregnancy. Obstet Gynecol Surv 2020; 75: 253-262.
[39] Effati-Daryani F, Mohammad-Alizadeh-Charandabi S, Mohammadi A, Zarei S and Mirghafourvand M. Fatigue and sleep quality in different trimesters of pregnancy. Sleep Sci 2021; 14: 69-74.
[40] Wang L and Jin F. Association between maternal sleep duration and quality, and the risk of preterm birth: a systematic review and meta-analysis of observational studies. BMC Pregnancy Childbirth 2020; 20: 125.
[41] Pengo MF, Won CH and Bourjeily G. Sleep in women across the life span. Chest 2018; 154: 196-206.
[42] Wang R, Xu M, Yang W, Xie G, Yang L, Shang L, Zhang B, Guo L, Yue J, Zeng L and Chung MC. Maternal sleep during pregnancy and adverse pregnancy outcomes: a systematic review and meta-analysis. J Diabetes Investig 2022; 13: 1262-1276.
[43] Kneitel AW, Treadwell MC and O'Brien LM. Effects of maternal obstructive sleep apnea on

fetal growth: a case-control study. J Perinatol 2018; 38: 982-988.
[44] Yang L, Xi B, Zhao M and Magnussen CG. Association of sleep duration with all-cause and disease-specific mortality in US adults. J Epidemiol Community Health 2021; [Epub ahead of print].
[45] Gooley JJ, Mohapatra L and Twan DCK. The role of sleep duration and sleep disordered breathing in gestational diabetes mellitus. Neurobiol Sleep Circadian Rhythms 2018; 4: 34-43.
[46] Wilson DL, Walker SP, Fung AM, Pell G, O'Donoghue FJ, Barnes M and Howard ME. Sleep-disordered breathing in hypertensive disorders of pregnancy: a BMI-matched study. J Sleep Res 2018; 27: e12656.
[47] Tsai SY, Lin JW, Kuo LT, Lee CN and Landis CA. Nighttime sleep, daytime napping, and labor outcomes in healthy pregnant women in Taiwan. Res Nurs Health 2013; 36: 612-622.
[48] Zafarghandi N, Hadavand S, Davati A, Mohseni SM, Kimiaiimoghadam F and Torkestani F. The effects of sleep quality and duration in late pregnancy on labor and fetal outcome. J Matern Fetal Neonatal Med 2012; 25: 535-537.
[49] Nakahara K, Michikawa T, Morokuma S, Ogawa M, Kato K, Sanefuji M, Shibata E, Tsuji M, Shimono M, Kawamoto T, Ohga S and Kusuhara K; Japan Environment and Children's Study Group. Association of maternal sleep before and during pregnancy with preterm birth and early infant sleep and temperament. Sci Rep 2020; 10: 11084.
[50] Liu YH, Lee CS, Yu CH and Chen CH. Effects of music listening on stress, anxiety, and sleep quality for sleep-disturbed pregnant women. Women Health 2016; 56: 296-311.
[51] Minar M, Habanova H, Rusnak I, Planck K and Valkovic P. Prevalence and impact of restless legs syndrome in pregnancy. Neuro Endocrinol Lett 2013; 34: 366-371.
[52] Yang Z, Zhu Z, Wang C, Zhang F and Zeng H. Association between adverse perinatal outcomes and sleep disturbances during pregnancy: a systematic review and meta-analysis. J Matern Fetal Neonatal Med 2022; 35: 166-174.
[53] Heazell A, Li M, Budd J, Thompson J, Stacey T, Cronin RS, Martin B, Roberts D, Mitchell EA and McCowan L. Association between maternal sleep practices and late stillbirth - findings from a stillbirth case-control study. BJOG 2018; 125: 254-262.
[54] Okun ML, Roberts JM, Marsland AL and Hall M. How disturbed sleep may be a risk factor for adverse pregnancy outcomes. Obstet Gynecol Surv 2009; 64: 273-280.
[55] Okun ML, Schetter CD and Glynn LM. Poor sleep quality is associated with preterm birth. Sleep 2011; 34: 1493-1498.