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Association between sleep during pregnancy and birth outcomes: a prospective cohort study

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Abstract

Objective A prospective cohort study was conducted to investigate sleep status during the early and second trimester of pregnancy in pregnant women on adverse birth outcome, such as preterm birth, low birth weight and small for gestational age.

Methods Multivariable logistic regression models were used to analyze the association of sleep status during the early and second trimester of pregnancy with adverse birth outcomes and generated the odds ratio and 95% confidence interval.

Results 5,418 pregnant women were included in the analysis. In the multivariable model, compared with 7.1–8 h/night, sleep ≤ 7 h/night during second trimester increases the risk of preterm birth (OR: 1.43, 95% CI: 1.12,1.85), and the risk of preterm birth was decreased in pregnant women who slept > 9 h/night (OR: 0.79, 95% CI: 0.53,0.93). Sleep quality, and sleep changes in the early and second trimesters, and sleep duration in the early pregnancy were not statistically associated with preterm birth, low birth weight and small for gestational age.

Conclusions Short sleep duration during pregnancy is associated with a higher risk of preterm birth and longer sleep duration at night is associated with a lower risk of preterm birth, but the latter needs further verification. Sleep status during pregnancy was not associated with low birth weight and small for gestational age. In order to reduce risk of adverse birth outcomes, sleep problems in pregnant women should be strengthened during pregnancy care.

Clinical trial number Not applicable.

Keywords Adverse birth outcomes, Cohort study, Sleep duration, Sleep quality

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Introduction

Adverse birth outcomes are a major public health problem worldwide. Common adverse birth outcomes include preterm birth (PTB), low birth weight (LBW) and small for gestational age (SGA) [1–3]. The incidence of PTB, LBW and SGA is estimated to be 10.6% [1], 14.6% [2] and 9.7% [3] globally. In China, the incidence of PTB, LBW and SGA were reported to be 6.4% [4], 5.2% [5] and 10.1% [6] respectively. Adverse birth outcomes not only increase perinatal morbidity and mortality, but also have lasting effects on the growth and development of neonates and even health throughout the life cycle [7–9].

Pregnant women are more prone to sleep disorders due to the influence of physiological and social factors [10]. Existing research has found that sleep disorders during pregnancy, including insomnia, sleep apnea, and obstructive ventilation disorder, can lead to adverse birth outcomes [11–13]. Similarly, quality and duration of sleep at night were also reported to be associated with adverse outcomes. Studies in some countries have reported that women with PSQI > 5 (Pittsburgh sleep quality index, PSQI) and insufficient sleep duration during pregnancy had an increased risk of PTB [14–16], LBW and SGA [17–19], while other studies found no association between night sleep quality or duration and adverse outcomes [20–22]. Several studies in China have also reported that poor sleep quality and short sleep duration during pregnancy are associated with an increased risk of PTB, LBW and SGA [23–25]. Other studies, however, have found no link between sleep duration and PTB and LBW [24, 26]. In general, the existing research results are not uniform, which may be related to the differences in regional and research conditions, so more research is necessary.

This study is based on data from the Tongji Shuangliu birth cohort (TSBC), and aims to examine the effects of sleep quality and duration during pregnancy on adverse birth outcomes, so as to provide more evidence for current research in this field.

Materials and methods

Inclusion and exclusion criteria

From 2017 to 2020, the TSBC enrolled women aged 18–40 years with a singleton pregnancy in the Shuangliu Maternal and Child Health Hospital in Chengdu, China. Details of this birth cohort have been reported elsewhere [27]. Briefly, pregnant women who attended antenatal care and had an gestational age ≤ 15 weeks were invited to participate in our study. Pregnant women were excluded if they (1) conceived the fetus using assisted reproductive technology, such as in-vitro fertilization and intrauterine insemination; (2) reported severe chronic disease or infectious disease like cancer, tuberculosis, and HIV infection; (3) did not give written consent for participation or was unable to complete the questionnaire.

Of 7281 pregnant women, 18 were diagnosed with hypertension and diabetes before pregnancy or had blood glucose ≥ 7.0 mmol/L during early pregnancy and 2 pregnant women with gestational age ≥ 42 were excluded. 1690 women were missing interim sleep data, and 153 women were missing covariate data. Finally, 5418 pregnant women were included in the analysis. A total of 5418 pregnant women were invited to complete a structured questionnaire at ≤ 15 weeks (early pregnancy) and 24–28 weeks (second trimester) of pregnancy.

Assessment of sleep

(a) During the early pregnancy and the second trimester, PSQI was used to assess the quality of sleep during the previous week. PSQI > 5 was defined as poor sleep quality, and PSQI ≤ 5 was defined as good sleep quality and was set as the control group [28]. (b) Sleep duration of the past week in the early and second trimester of pregnancy was estimated by asking participants the question, "how many hours of actual sleep did you get per night in the past week?", and was divided into four grades based on the classification method of previous literature: ≤7 h of nocturnal sleep is defined as short sleep time, 7.1–8 h of nocturnal sleep is defined as adequate sleep time and control group, 8.1–9 h of nocturnal sleep, > 9 h of nocturnal sleep is defined as longer sleep time [24, 29]. (c) Changes in sleep quality from the early pregnancy to the second trimester were divided into four mutually exclusive groups according to good/poor sleep quality during the early and second trimesters: always good (Sleep quality were all good in the early and second trimesters and were set as the control group), always poor (Both early and middle trimesters were poor), from good to poor, from poor to good.

Measurement of birth outcomes

Information on birth outcomes was collected through medical records. Full term was defined as 37 to 41 weeks [30], and PTB was defined as less than 37 weeks of gestation [14]; LBW is defined as birth weight < 2500 g, macrosomia defined as birth weight ≥ 4000 g, and normal birth weight (NBW) defined as weight ≥ 2 500 g to < 4 000 g [31]; SGA defines newborns whose birth weight is below the 10th percentile of the average weight of children for the same gestational age, and larger than gestational age (LGA) is defined as a newborn whose birth weight is above the 90th percentile of the average weight of children for the same gestational age [32].

Assessment of covariates

Pregnant women in the early pregnancy and the second trimester were interviewed by trained investigators

to complete structured questionnaires on the maternal sociodemographic characteristics, lifestyle and health status.

Maternal age was treated as a continuous variable. Employment was categorized as two groups: unemployed and employed. Average family income was categorized as two groups: 49,999 yuan ≤ and ≥ 50,000 yuan. Education was categorized as two groups: senior high school or lower and college or above. Place of residence was categorized as two groups: urban and rural area. Smoking was categorized as three groups: current, former and never. Drinking was categorized as three groups: current, former and never. Parity was categorized as: 0 and ≥ 1. The Chinese version of the Pregnancy Physical Activity Questionnaire (PPAQ) [33] was used to calculate the past week physical activity energy expenditure (MET-H/week) in the early pregnancy, which has been validated among pregnant women in China [34]. Pre-pregnancy weight was self-reported by the women, and the weight of women in the second trimester was measured by a hospital body fat meter. Weight and standing height were measured with light clothes and no shoes. Pre-pregnancy BMI (kg/m^2) was calculated using self-reported pre-pregnancy weight (kg) divided by height squared (m), and was divided into four categories based on Chinese criteria: underweight (< 18.5 kg/m^2), normal weight (18.5–23.9 kg/m^2), overweight (24.0–27.9 kg/m^2) and obese (≥ 28.0 kg/m^2) [35]. Depressive symptoms in early pregnancy were measured using the Edinburgh Postnatal Depression Scale (EPDS), a depression screening tool developed to specifically assess depressive symptoms in perinatal women where higher scores indicate more severe depressive symptoms [36]. Anxiety symptoms in early pregnancy were measured using the Zung self-rating Anxiety Scale (SAS). The SAS is widely used as a self-assessment tool for detecting anxiety symptoms in clinical practice and showed adequate validity and reliability in a previous study [37]. In the present study, an EPDS scores ≥ 13 and SAS scores ≥ 50 were used as the cut-off value to identify the presence of antenatal depression and anxiety [38]. Hypertensive disorders in pregnancy (HDP) was divided into two groups: yes and no; Gestational diabetes mellitus (GDM) was divided into two groups: yes and no.

Statistical analyses

Baseline characteristics were presented as mean ± standard deviation (SD) or median (interquartile range) for continuous variables, and n (%) for categorical variables. *T* tests, Mann-Whitney *U* tests and $\chi 2$ tests were used to analyze the relationships of basic characteristics between birth outcome categories. Multivariable logistic regression was used to examine the relationship between sleep and birth outcomes. Odds ratios (ORs) and their 95% confidence intervals (95% CIs) were calculated in a stepwise manner. Unadjusted model. Model 1: Adjusted for maternal age, employment, education, place of residence, family income, smoking, drinking, physical activity in the early pregnancy, parity, pre-pregnancy BMI, depressive and anxiety symptoms. Model 2 was adjusted for covariates in Model 1 plus HDP and GDM. Statistical analyses were conducted by SAS version 9.4 (SAS Institute, Cary, NC) with two-sided *P* values < 0.05 as the level of significance.

Results

Baseline characteristics

Of 5418 women included in the study, the mean maternal age of all included subjects was 26.6 ± 3.7 years. 1003 (18.51%) had short nighttime sleep duration in early pregnancy, 2197 (40.55%) slept 7.1–8 h per night in early pregnancy, and 941(17.36%) had long nighttime sleep duration in early pregnancy. Sleep duration in early pregnancy varied significantly across several socio-demographic and lifestyle characteristics (Table 1). Compared with women with normal nighttime sleep duration, those with short nighttime sleep duration were more likely to be older, less educated, unemployed, multiparous, current smokers, and to have a higher physical activity level, and depressive and anxiety symptoms in early pregnancy (all $P < 0.05$).

Relationship between nocturnal sleep quality, sleep duration and PTB during pregnancy

In total, 224 (4.13%) women had a premature delivery. After adjusting for confounding factors, compared with women with a nighttime sleep duration of 7.1–8 h/night during the second trimester, those who slept ≤ 7 h/night had a higher risk of PTB (OR: 1.43, 95%CI: 1.12, 1.85), and those who slept > 9 h/night had a lower risk of PTB (OR:0.79, 95%CI: 0.53, 0.93) in the model 2. Sleep duration in early pregnancy and sleep quality during pregnancy were not statistically associated with the risk of PTB ($P > 0.05$), as detailed in Table 2.

Relationship between nocturnal sleep quality, sleep duration and LBW and SGA during pregnancy

126 (2.32%) women delivered a LBW newborn, and 303 (5.59%) women delivered an SGA newborn. The unadjusted model showed that there was no association between night sleep quality, sleep duration during pregnancy and LBW and SGA. After adjustment for confounder factors, there was still no association was found between night sleep quality and sleep duration during pregnancy and LBW and SGA, as detailed in Tables 3 and 4.

At the same time, binary logistic regression was used to analyze the influence of changes in sleep quality during

Table 1 Demographic and clinical characteristics of the study population

Characteristic	Nighttime sleep duration in mid pregancy (hours/night)				*P* value[†]
	≤ 7 (*n* = 1003)	7.1-8 (*n* = 2197)	8.1-9 (*n* = 1477)	> 9 (*n* = 741)	
Maternal age, years	27.3 (3.6)	26.8 (3.6)	26.3 (3.7)	25.4 (3.5)	< 0.001
Gestational age, weeks	38.8 (1.3)	38.8 (1.2)	38.8 (1.2)	38.9 (1.2)	0.07
Residence					< 0.001
Rural	259 (25.82)	466 (21.21)	295 (19.97)	124 (16.73)	
Urban	744 (74.18)	1731 (78.79)	1182 (80.03)	617 (83.27)	
Education level					0.004
Senior high school or lower	573 (57.13)	1214 (55.26)	826 (55.92)	465 (62.75)	
College or above	430 (42.87)	983 (44.74)	651 (44.08)	276 (37.25)	
Employment					< 0.001
Employed	535 (53.34)	1197 (54.48)	777 (52.61)	305 (41.16)	
Unemployed	468 (46.66)	1000 (45.52)	700 (47.39)	436 (58.84)	
Average family income (RMB per year)					0.06
≤ 49,999	431 (42.97)	910 (41.42)	603 (40.83)	344 (46.42)	
≥ 50,000	572 (57.03)	1287 (58.58)	874 (59.17)	397 (53.58)	
Pre-pregnancy BMI (kg/m^2)[c]					0.37
Underweight	161 (16.05)	397 (18.07)	295 (19.97)	148 (19.97)	
Normal	702 (69.99)	1492 (67.91)	983 (66.55)	487 (65.72)	
Overweight	114 (11.37)	246 (11.20)	151 (10.22)	85 (11.47)	
Obese	26 (2.59)	62 (2.82)	48 (3.25)	21 (2.83)	
Parity					0.0002
0	509 (50.75)	1250 (56.90)	871 (58.97)	441 (59.51)	
≥ 1	494 (49.25)	947 (43.10)	606 (41.03)	300 (40.49)	
Physical activity, MET hours/week	141.8 (85.2)	138.0 (82.1)	129.0 (79.3)	121.1 (81.0)	< 0.001
Smoking status					0.03
Never	932 (92.92)	2067 (94.08)	1379 (93.36)	678 (91.50)	
Former	45 (4.49)	106 (4.82)	70 (4.74)	45 (6.07)	
Current	26 (2.59)	24 (1.09)	28 (1.90)	18 (2.43)	
Drinking status					0.09
Never	787 (78.46)	1733 (78.88)	1205 (81.58)	576 (77.73)	
Former /Current	216 (21.54)	464 (21.12)	272 (18.42)	165 (22.27)	
HDP, Yes	21 (2.09)	50 (2.28)	35 (2.37)	19 (2.56)	0.93
GDM, Yes	75 (7.48)	164 (7.46)	88 (5.96)	42 (5.67)	0.14
Depressive symptom	98 (9.77)	165 (7.51)	95 (6.43)	43 (5.80)	0.004
Anxiety symptom	139 (13.86)	179 (8.15)	125 (8.46)	77 (10.39)	< 0.001

Abbreviations: BMI = body mass index; GDM = gestational diabetes mellitus; GWG = gestational weight gain; HDP = hypertensive disorders in pregnancy. Data are mean (standard deviation) or median (interquartile range) for continuous variables and n (%) for categorical variables. Percentages may not sum up to 100% because of rounding. [†]*P* values were derived from analysis of variance or Kruskal-Wallis H tests for continuous variables according to data distribution and chi-square tests for categorical variables

pregnancy on adverse birth outcomes, and no statistical significance was found in all model results. See Table 5 for details.

Discussion

Main findings

Based on the TSBC, this study aimed to examine the relationship between night sleep quality and sleep duration and adverse birth outcomes during pregnancy. The results showed that insufficient sleep duration during pregnancy was associated with an increased risk of PTB, but longer sleep duration was associated with a lower risk of PTB, and night sleep quality and duration during pregnancy were not associated with LBW and SGA.

Interpretation, the association between sleep during pregnancy and adverse birth outcomes

This study found that short sleep duration during the second trimester was associated with an increased risk of PTB, a finding consistent with two recent meta-analysis studies [39, 40]. Some other studies have found that sleep at different trimester of pregnancy is also associated with an increased risk of preterm birth. Micheli et al. assessed sleep in the third trimester (28–32 weeks) of 1091 singleton pregnancies and found that women who slept less

Table 2 Relationship between nocturnal sleep duration and PTB

	PTB (%)	Unadjusted	Model 1[†]	Model 2[‡]
		OR (95% CI)	OR (95% CI)	OR (95% CI)
< 15 weeks				
Sleep quality				
Good	165 (73.66)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Poor	59 (26.34)	1.08 (0.80,1.47)	0.96 (0.69,1.33)	0.95 (0.68,1.32)
Sleep duration (h)[b]				
≤ 7	53 (23.66)	1.31 (0.92,1.85)	1.28 (0.90,1.82)	1.28(0.90,1.83)
7.1-8	90 (40.18)	1.00 (reference)	1.00 (reference)	1.00 (reference)
8.1-9	54 (24.11)	0.89 (0.63,1.25)	0.90 (0.64,1.28)	0.91 (0.64,1.28)
> 9	27 (12.05)	0.89 (0.57,1.37)	0.90 (0.58,1.41)	0.90 (0.58,1.41)
24–28 weeks				
Sleep quality				
Good	153 (68.30)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Poor	71 (31.70)	1.09 (0.82,1.45)	1.05 (0.78,1.41)	1.05 (0.78,1.40)
Sleep duration (h)				
≤ 7	53 (23.66)	1.47 (1.10,1.89)	1.45 (1.11,1.88)	1.43 (1.12,1.85)
7.1-8	144 (64.29)	1.00 (reference)	1.00 (reference)	1.00 (reference)
8.1-9	21 (9.38)	0.90 (0.57,1.44)	0.93 (0.58,1.49)	0.83 (0.58,1.49)
> 9	6 (2.68)	0.75 (0.53,0.90)	0.76 (0.55,0.92)	0.79 (0.53,0.93)

Abbreviations: CI, confidence interval; OR, odds ratio; PTB, preterm birth. [†] Model 1: Adjusted for maternal age, employment, education, residence, and family income, smoking, drinking, physical activity during early pregnancy, parity, pre-pregnancy BMI, depressive and anxiety symptoms.[‡] Model 2 was adjusted for covariates in Model 1 plus HDP and GDM

Table 3 Relationship between nocturnal sleep duration and LBW

	LBW[a]	Unadjusted	Model 1[†]	Model 2[‡]
		OR (95% CI)	OR (95% CI)	OR (95% CI)
< 15 weeks				
Sleep quality[a]				
Good	88 (69.84)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Poor	38 (30.16)	1.32 (0.90,1.95)	1.29 (0.85,1.95)	1.28 (0.85,1.95)
Sleep duration (h)				
≤ 7	24 (19.05)	0.92 (0.57,1.48)	0.95 (0.59,1.55)	0.95 (0.58,1.55)
7.1-8	58 (46.03)	1.00 (reference)	1.00 (reference)	1.00 (reference)
8.1-9	31 (24.60)	0.79 (0.51,1.23)	0.78 (0.50,1.21)	0.78 (0.50,1.21)
> 9	13 (10.32)	0.66 (0.36,1.22)	0.63 (0.34,1.16)	0.63 (0.34,1.16)
24–28 weeks				
Sleep quality[a]				
Good	83 (65.87)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Poor	43 (34.13)	1.23 (0.85,1.79)	1.23 (0.84,1.80)	1.22 (0.84,1.79)
Sleep duration (h)				
≤ 7	24 (19.05)	1.00 (0.63,1.58)	1.05 (0.66,1.66)	1.05 (0.66,1.67)
7.1-8	89 (70.63)	1.00 (reference)	1.00 (reference)	1.00 (reference)
8.1-9	8 (6.35)	0.55 (0.27,1.14)	0.53 (0.26,1.11)	0.53 (0.25,1.10)
> 9	5 (3.97)	1.43 (0.57,3.58)	1.34 (0.53,3.38)	1.35 (0.54,3.40)

Abbreviations: CI, confidence interval; OR, odds ratio; LBW, low birth weight. [a] 227 women were excluded from the LBW analysis due to delivery Macrosomia. [†] Model 1: Adjusted for maternal age, employment, education, residence, and family income, smoking, drinking, physical activity during early pregnancy, parity, pre-pregnancy BMI, depressive and anxiety symptoms. [‡] Model 2 was adjusted for covariates in Model 1 plus HDP and GDM

than 5 h had an increased risk of preterm delivery [14] Similarly, Li et al. assessed sleep duration in 1082 healthy women with single fetal pregnancies at 8–12, 24–28, and 32–36 weeks of gestation and found that participants with short sleep duration (≤ 7 h) at 32–36 weeks were more likely to report PTB [23]. However, other studies have reported different results. Previous case-control studies by Guendelman et al. also found no link between short sleep duration and PTB [41]. Two other large-sample prospective cohort studies assessing the relationship between sleep duration and poor birth outcomes in late pregnancy in Chinese women and throughout pregnancy

Table 4 Relationship between nocturnal sleep duration and SGA

	SGA[a]	Unadjusted	Model 1[†]	Model 2[‡]
		OR (95% CI)	OR (95% CI)	OR (95% CI)
< 15 weeks				
Sleep quality				
Good	230 (75.91)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Poor	73 (24.09)	0.97 (0.74,1.27)	0.89 (0.66,1.19)	0.89 (0.66,1.19)
Sleep duration (h)				
≤ 7	53 (17.49)	1.08 (0.77,1.51)	1.12 (0.80,1.58)	1.11 (0.79,1.57)
7.1-8	112 36.96)	1.00 (reference)	1.00 (reference)	1.00 (reference)
8.1-9	92 (30.36)	1.25 (0.94,1.67)	1.22 (0.91,1.63)	1.21 (0.90,1.61)
> 9	46 (15.18)	1.23 (0.86,1.76)	1.17 (0.82,1.68)	1.17 (0.81,1.68)
24–28 weeks				
Sleep quality				
Good	218 (71.95)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Poor	85 (28.05)	0.92 (0.72,1.20)	0.92 (0.71,1.20)	0.92 (0.70,1.19)
Sleep duration (h)				
≤ 7	53 (17.49)	0.98 (0.72,1.34)	1.03 (0.75,1.42)	1.03 (0.75,1.41)
7.1-8	204 (67.33)	1.00 (reference)	1.00 (reference)	1.00 (reference)
8.1-9	37 (12.21)	1.11 (0.78,1.60)	1.08 (0.75,1.56)	1.08 (0.75,1.57)
> 9	9 (2.97)	1.14 (0.57,2.29)	1.07 (0.53,2.14)	1.04 (0.52,2.10)

Abbreviations: CI, confidence interval; OR, odds ratio; SGA, small for gestational age. [a] 700women were excluded from the SGA analysis due to delivery LGA. [†] Model 1: Adjusted for maternal age, employment, education, residence, and family income, smoking, drinking, physical activity during early pregnancy, parity, pre-pregnancy BMI, depressive and anxiety symptoms. [‡] Model 2 was adjusted for covariates in Model 1 plus HDP and GDM

Table 5 Relationship between sleep changes during pregnancy and PTB

	Total	Unadjusted	Model 1[†]	Model 2[‡]
		OR (95% CI)	OR (95% CI)	OR (95% CI)
PTB				
Always good	119 (53.13)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Always poor	25 (11.16)	0.99 (0.64,1.54)	0.86 (0.54,1.38)	0.84 (0.52,1.33)
From good to poor	46 (20.54)	1.26 (0.89,1.78)	1.25 (0.88,1.77)	1.27 (0.90,1.81)
From poor to good	34 (15.18)	1.30 (0.88,1.93)	1.17 (0.78,1.76)	1.18 (0.79,1.78)
LBW[a]				
Always good	68 (53.97)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Always poor	23 (18.25)	1.64 (1.02,2.67)	1.65 (0.99,2.77)	1.62 (0.97,2.72)
From good to poor	20 (15.87)	0.95 (0.58,1.58)	0.96 (0.58,1.59)	0.96 (0.58,1.60)
From poor to good	15 (11.90)	0.99 (0.57,1.75)	0.96 (0.53,1.72)	0.97 (0.54,1.74)
SGA[b]				
Always good	183 (60.40)	1.00 (reference)	1.00 (reference)	1.00 (reference)
Always poor	38 (12.54)	1.01 (0.70,1.44)	0.95 (0.64,1.39)	0.94 (0.64,1.39)
From good to poor	47 (15.51)	0.83 (0.60,1.16)	0.83 (0.60,1.16)	0.82 (0.59,1.15)
From poor to good	35 (11.55)	0.86 (0.59,1.24)	0.77 (0.52,1.14)	0.77 (0.52,1.13)

Abbreviations: CI, confidence interval; OR, odds ratio; PTB, preterm birth; LBW, low birth weight; SGA, small for gestational age. [a] 227 women were excluded from the LBW analysis due to delivery Macrosomia. [b] 700women were excluded from the SGA analysis due to delivery LGA. [†] Model 1: Adjusted for maternal age, employment, education, residence, and family income, smoking, drinking, physical activity during early pregnancy, parity, pre-pregnancy BMI, depressive and anxiety symptoms. [‡] Model 2 was adjusted for covariates in Model 1 plus HDP and GDM

in Japanese women also found no association between short sleep duration and the risk of PTB [20, 24]. Different definitions of sleep duration, gestational age of concern, corrected covariates, and sample size may explain this controversial result.

Maternal sleep efficiency often decreases with the progression of pregnancy, resulting in reduced sleep duration, which may be related to physiological and psychological changes during pregnancy, especially in the late pregnancy, including significant changes in hormone levels, physical discomfort, night awakenings, childbearing anxiety, stress, increased fetal movement, decreased residual capacity of lung function, airway obstruction, etc. The mechanisms underlying the current association between short sleep duration and PTB are not clear, and some mechanisms may explain the association between

lack of sleep and PTB [40, 42]. One possibility is the effect of excessive inflammatory reaction. Sleep deprivation will promote the increase of inflammatory cytokines such as interleukin-6 (IL-6) and IL-8, thereby stimulating the production of prostaglandins in pregnancy tissue, leading to cervical maturation and uterine contraction [23, 43].

Studies have reported that longer sleep duration (>9 h or >10 h) is significantly associated with impaired glucose tolerance, coronary heart disease, cardiovascular events, stroke, and mortality [29, 44]. A study by Yang et al. reported an increased incidence of PTB in pregnant women who slept longer [45]. Kajeepeta et al. showed that women who reported long sleep duration and fatigue in the first 6 months of pregnancy had an increased risk of PTB, while women who reported long sleep duration (≥9 h) and no fatigue had no statistically significant risk of PTB, and fatigue may be a new risk factor for PTB [15]. Notably, this study found that longer sleep duration during the second trimester was associated with a lower risk of PTB, and differences in study design and definition of long sleep duration may lead to conflicting findings. We did not find a mechanism to explain the protective effect of longer sleep duration on pregnant women. It may be that longer sleep duration counteracts the effects of fatigue. In conclusion, the results of this study need further verification. In addition, this study did not find an association between sleep duration in early pregnancy and PTB, which is consistent with the results of Li and Nakahara et al. [20, 23]. Data analysis in this study showed that, compared with the second trimester, women in the early pregnancy subjectively reported longer sleep duration. The difference in sleep duration between the early pregnancy and the second trimester may explain the relationship between sleep duration in different stages of pregnancy and PTB, and the lack of sleep information in some subjects may also be one of the reasons.

Analysis of the data in this study found that sleep quality during pregnancy was not associated with PTB. A study by Du et al. in China also reported consistent results [22, 23]. Other findings suggest that poor sleep quality during pregnancy may be a risk factor for PTB. A small cohort study in the United States found that PSQI>5 in early pregnancy was associated with PTB, with a 25% increase in the chance of PTB for every percentage point increase [46]. However, this study only corrected for obstetric risk, income, and stress. A Chinese cohort with a sample size of 688 found that women with poor sleep quality in the second and third trimesters had a 5-fold and 3-fold increased risk of PTB, respectively [47]. The results were inconsistent, possibly due to sample size, pregnancy, and adjusted confounding factors.

The study also did not find an association between sleep during pregnancy and LBW and SGA. Consistent with some research findings [14, 18, 26]. However, two large-sample cohort studies in China during the third trimester found that poor sleep quality (PSQI>5) was associated with an increased risk of LBW [26] and sleep duration≤7 h was a risk factor for SGA [17]. Another prospective study also reported that women with poor sleep quality or sleep deprivation (<7 h vs. >9 h) at 30 weeks gestation had lower baby weight [48]. We speculate that the controversial findings may be related to the study environment, sleep classification, and the focus on differences in sleep gestational age. The relationship between sleep during pregnancy and birth weight of newborn remains to be further verified.

Overall, the available research results are inconsistent, but some of the findings suggest that poor sleep leads to the possibility of adverse birth outcome cannot be ignored. Adverse birth outcomes are not only bad for the short-term physical health of newborns harmful effects and increased susceptibility to disease in adulthood. Identification of possible risk factors is helpful for pregnancy preparation, prevention, screening and early intervention during pregnancy, and will have a positive impact on the reduction of the incidence of adverse birth outcomes and good birth and good upbringing.

Strengths and limitations

This was a prospective cohort study with a large sample size, which has high statistical power and provides a more accurate estimate of the association between sleep and birth outcomes. The study has some limitations. First, sleep information was evaluated by PSQI, which only asked about sleep-related information over the past week rather than objective measurements such as polysomnography. Some studies have shown that pregnant women actually sleep about 30 min less than they subjectively report, so sleep duration during pregnancy may be overestimated. When conditions permit, future studies can combine subjective reports with sleep assessed by more reliable devices such as polysomnography and wrist motion detectors. Secondly, although we adjusted sociodemographic characteristics, living habits, and health status, other residual confounding may still exist, such as fatigue, restless leg syndrome, sleep apnea, etc., which can be considered for inclusion in future studies. Moreover, the subjects included in this study only included pregnant women who went to Shuangliu Maternal and Child Health Hospital in Chengdu, China, and could not be extended to people in other areas, which could be further discussed by conducting multi-center studies in the future. This study did not collect sleep information during the third trimester of pregnancy, so it could not assess the relationship between sleep during the whole pregnancy and birth outcome. Future studies can

add the third trimester to make the study results more comprehensive.

Conclusions

Overall, this study did not observe the effects of maternal sleep quality and sleep duration on LBW and SGA, while found that insufficient sleep duration during pregnancy is an independent risk factor for PTB. We also found longer sleep duration may be associated with a lower risk of PTB, but this conclusion needs to be further verified. It is recommended that that prenatal care providers consider monitoring sleep in pregnant women during pregnancy, especially during the second trimester, and for pregnant women with insufficient sleep, pregnancy health personnel should intervene in time to reduce adverse delivery outcomes.

Abbreviations

PTB	Preterm birth
LBW	Low birth weight
SGA	Small for gestational age
PSQI	Pittsburgh sleep quality index
TSBC	Tongji shuangliu birth cohort
LGA	Larger than gestational age
BMI	Body mass index
EPDS	Edinburgh postnatal depression scale
SAS	Zung self-rating anxiety scale
HDP	Hypertensive disorders in pregnancy
GDM	Gestational diabetes mellitus
ORs	Odds ratios
CIs	Confidence intervals

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Author contributions

Libing Huang, Huanjun Chen: Conceptualization, Methodology, Formal analysis, Writing - Original Draft, Writing - Review & Editing; Fuhui Yao: Revise & Editing; Zhonghan Sun: Data Curation, Validation, Software; Shijiao Yan: Supervision, Project administration; Yuwei Lai: Investigation, Visualization; Chuanzhu Lv: Funding acquisition, Project administration; Xiong-Fei Pan: Resources, Conceptualization, Writing - Review & Editing; Rixing Wang, Xingyue Song: Resources, Conceptualization, Writing - Review & Editing, Funding acquisition. Libing Huang, Huanjun Chen contributed equally to this work. All authors judged and reviewed the manuscript and approve the final version, and have obtained permission from Xiong-Fei Pan, Rixing Wang and Xingyue Song corresponding authors before submission.

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Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with ethical principles of the Declaration of Helsinki and approved by the Ethics Committee of the Tongji Medical College, Huazhong University of Science (Wuhan, China) (number: 2017[S225]). All participants provided written informed consent during recruitment.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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