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SCIENTIFIC INVESTIGATIONS

Sleep position and breathing in late pregnancy and perinatal outcomes

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Study Objectives: Body position during sleep has been related to breathing in adults with obstructive sleep apnea (OSA). While sleep-disordered breathing is common, little information is available on the relation between sleep position and maternal breathing in pregnancy. We examined associations between the supine position, maternal breathing, and perinatal outcomes.

Methods: Women with a singleton, uncomplicated pregnancy were recruited and underwent an ambulatory overnight sleep study between 33 to 36 weeks using the Watch-PAT device. Their medical records were also reviewed.

Results: A total of 148 pregnant women were recruited (mean age: 33 ± 4 years; mean body mass index: 27.6 ± 4.0 kg/m^2). They spent approximately one-half of their sleeping time in a supine position. The group's mean apnea-hypopnea index (AHI) was 3.6 events/h in the supine position and 2.9, 2.6, and 2.1 events/h for the prone, right, and left positions, respectively. Median AHI and oxygen desaturation index were higher and SpO_2 nadir was lower in the supine versus nonsupine position ($P < .0001$, $P < .0001$, and $P = .006$, respectively). Peripheral oxygen saturation nadir was associated with the percentage of time spent sleeping in the supine position ($P = .02$). No correlations were found between supine sleep position and perinatal outcomes. There were no differences in the distributions of body positions between women with and those without OSA.

Conclusions: Women in the third trimester of pregnancy with or without OSA spent large proportions of sleeping time in a supine position. Supine position was associated with more respiratory events and more and deeper oxygen desaturation events. They were not associated with perinatal outcomes.

Clinical Trial Registration: Registry: ClinicalTrials.gov; Name: Fetal Outcome of Sleep Disordered Breathing During Pregnancy; URL: https://clinicaltrials.gov/ct2/show/NCT00931099; Identifier: NCT00931099.

Keywords: body position in sleep, supine sleep, pregnancy, obstructive sleep apnea, sleep-disordered breathing, perinatal outcomes

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BRIEF SUMMARY

Current Knowledge/Study Rationale: Sleep position has been related to breathing in adults with obstructive sleep apnea. In pregnancy, interventions to modify sleep position have been postulated to improve maternal and fetal outcomes based on the link found between maternal sleep position, fetal growth, and late-pregnancy stillbirth. Little information is available on the relation between sleep position, maternal breathing in late pregnancy, and perinatal outcomes.
Study Impact: In the present study, we show that women in the third trimester of pregnancy spent approximately one-half of their sleeping time in a supine position, irrespective of the presence of obstructive sleep apnea. Although supine sleep positions were associated with more respiratory events, more oxygen desaturation events, and deeper nocturnal oxygen desaturation, they were not associated with adverse perinatal outcomes.

INTRODUCTION

Body position during sleep has been linked to breathing in adults with obstructive sleep apnea (OSA). A supine position compromises airway stability, and it has been shown to increase the number of respiratory events compared with the lateral position.[1,2] In pregnancy, maternal body position has been linked to fetal growth restriction and late pregnancy stillbirth,[3,4] and interventions to modify sleep position have been postulated to improve maternal and fetal outcomes.[5] Snoring and disturbed breathing during sleep affect almost one-half of all pregnant women,[6,7] and OSA has been associated with adverse maternal and infant outcomes[8–11]; however, no associations were found between maternal OSA and stillbirth in population-based studies.[12–15] Supine positions may influence maternal breathing and fetal health via exacerbating symptoms of OSA. The

frequency of supine positions during pregnancy and their relationship with maternal breathing and fetal outcome merit investigation. In a study of 51 women it was found that the majority of women (82%) spent some time in a supine position, with a median proportion of 27% of total time.[16] In another interventional study, reducing the time spent in the supine position improved maternal oxygen saturations and fetal heart decelerations.[3,4]

The accumulating data on body position and breathing during sleep in pregnancy prompted us to examine supine sleep positions in relation to maternal breathing and fetal outcome in a cohort of 148 women in the third trimester of pregnancy. We hypothesized that the supine position will be associated with more respiratory events and reduced nocturnal oxygenation in comparison to the nonsupine positions and that sleeping more in the supine position will adversely affect perinatal outcomes.

METHODS

The study was approved by the institutional review board of the Tel Aviv Medical Center, and informed consent was obtained from all participants. Women with a singleton, uncomplicated pregnancy who attended a low-risk obstetric surveillance outpatient clinic were recruited at the end of their second trimester (gestational week 25–27) between November 2012 and June 2016. All participants completed a questionnaire on medical and obstetric history, smoking exposure history, and current pregnancy complications. They all underwent an ambulatory overnight sleep study between 33 to 36 weeks of gestation. The Watch-PAT 200 device (Itamar Medical; Caesarea, Israel) that had been validated in pregnancy and shown to correlate well with polysomnography was used.[17] The Watch-PAT device provides information on the time spent in each body position and the respiratory indices (apnea-hypopnea index [AHI] and oxygen desaturation index [ODI]) in each position. In addition, it provides information on mean peripheral capillary oxygen saturation (SpO_2), SpO_2 nadir, and the time spent in SpO_2 <90% for the entire sleep study. The body position is determined by means of a 3-axes accelometer (2 horizontal and 1 vertical) positioned on the sternal notch. The 3 axes measure the gravity projections from which the position of the chest is calculated. Women with an AHI of more than 5 events/h per hour of sleep were considered as having OSA.

A medical records review was conducted by one of the researchers who was unaware of the sleep study results. Pertinent demographic and clinical information (sex, gestational age, birth weight, Apgar scores at 1 and 5 minutes) was collected. The neonatal birth-weight percentile was calculated according to sex and gestational age using a birth-centile curves reference standard from Israel.[18]

Statistical analysis

We conducted univariate analyses to examine maternal characteristics, body position, and position-specific breathing indices. For each woman, we calculated the AHI and ODI events during time spent in supine and nonsupine (right, left, and prone) sleep positions. Mean SpO_2 and SpO_2 nadir as well as percentage of time when SpO_2 <90% were also calculated per sleep position. We fitted mixed Poisson regression models to examine the impact of sleep position on AHI and ODI event counts, while controlling for time spent in each sleep position. Mixed linear regression models were used to examine mean differences of SpO_2, SpO_2 nadir, and SpO_2 <90% between supine and nonsupine sleep positions.

Bivariate analyses were applied to compare maternal characteristics and body-position preferences according to OSA status. Linear regression analysis was used to examine the association between maternal oxygen saturation and supine position during sleep adjusted for maternal smoking and current weight. Finally, we examined the association between maternal supine position during sleep and newborn birth-weight percentile. All statistical procedures were performed with SAS version 9.4 (SAS Institute, Cary, NC).

RESULTS

A total of 148 pregnant women were recruited. Their mean ± SD age was 33 ± 4 years (range: 23–46 years). The mean maternal body mass index (BMI) at enrollment was 27.6 ± 4.0 kg/m² (range: 19–41 kg/m²). One-half of the women were nulliparous, and 9 (6%) reported smoking during pregnancy. The women's characteristics, sleep study results, and perinatal outcomes are presented in **Table 1**. On average, the women slept in a supine position almost one-half of the time and almost one-fifth of the time in a right or left lateral position (**Table 1**).

Sleep-breathing characteristics in the supine and nonsupine sleep position are presented in **Table 2**, and the associations between sleep position and breathing parameters are presented in **Table 3**. Median AHI and ODI were significantly higher and SpO_2 nadir was significantly lower in the supine versus the nonsupine position. The supine position was associated with 60% more respiratory events (AHI) and a 2-fold increase in desaturation events per hour of sleep in comparison to the nonsupine sleep position.

No correlations were found between the percentage of time spent sleeping in the supine position and either the AHI or the mean SpO_2 measurements. There was a significant negative correlation between the percentage of time spent sleeping in the supine position and the SpO_2 nadir measurements ($r = -.17$, $P = .03$).

Thirty-two women (21%) had OSA. The mean AHI in the OSA group was 9.8 events/h (range: 5–21.6 events/h). The mean AHI was 3.6 events/h for the supine position (range: 0–31.5 events/h) compared with 2.9, 2.6, and 2.0 events/h for the prone, right, and left positions, respectively. There were no differences in the distributions of body positions during sleep between the women with and those without OSA.

For the entire cohort, women slept in a supine position 47% ± 26% of the time (range: 0–100%) and 53% ± 26% (range: 0–100%) in a nonsupine position. There were no differences in the percentage of time spent sleeping in the supine position between obese and nonobese women.

To further explore the effect of supine position on maternal breathing and perinatal outcomes, we compared women in the upper quartile of time spent sleeping in the supine position with women in the lower quartile and found no differences in AHI, gestational age, birth-weight percentile, or Apgar scores between the 2 groups. However, women in the lower quartile had a significantly higher mean SpO_2 nadir ($P = .02$) and an almost significant higher mean SpO_2 ($P = .07$). Linear regression analysis adjusted for BMI at enrollment and current smoking status showed a significant association between SpO_2 nadir as a dependent variable and percentage of time spent sleeping in the supine position as an independent variable (**Table 4**).

DISCUSSION

Body position during sleep has significant effects on maternal hemodynamics during pregnancy, and the supine position has been linked to adverse pregnancy outcomes, particularly

Table 1—Maternal sleep study and perinatal characteristics of pregnant women.

	Values
Maternal age, mean (SD), years	33 (4.0)
Nulliparous, n (%)	69 (51)
Maternal BMI at enrollment, mean (SD), kg/m^2	27.6 (4.0)
Current smokers, n (%)	8 (6)
Total sleep time in hours, mean (SD)	5.9 (1.2)
AHI, median (IQR, range), events/h	1.4 (3.9, 0–21)
SpO$_2$, mean (SD, range), %	96 (1.1, 92–98)
SpO$_2$ nadir, median (IQR, range), %	93 (3, 82–97)
Percentage of time spent in SpO$_2$ <90%, median (IQR, range)	0 (0, 0–35)
Percentage of time in a supine position, mean (SD)	47 (26)
Percentage of time in a prone position, mean (SD)	19 (21)
Percentage of time in a left-sided position, mean (SD)	18 (18)
Percentage of time in a right-sided position, mean (SD)	16 (20)
Mean gestational age at delivery, mean (SD), weeks	39.3 (1.3)
Birth-weight percentile, mean (SD)	60 (25)
Newborn sex, %	
Boys	60
Girls	40
Apgar score 1 minute, mean (SD)	8.8 (0.9)
Apgar score 1 minute <7, %	3
Apgar score 5 minutes, mean (SD)	9.8 (0.5)
Apgar score 5 minutes <7, %	0

N = 148. AHI = apnea-hypopnea index; BMI = body mass index; IQR = interquartile range; SpO$_2$ = peripheral oxygen saturation.

Table 2—Sleep-breathing characteristics by sleep position.

	Supine Position	Nonsupine Position
AHI, median (IQR)	1.7 (4.9)	0.8 (2.5)
ODI, median (IQR)	0.2 (1.3)	0 (0.6)
SpO$_2$, median (IQR)	96.5 (1.3)	96.5 (1.4)
SpO$_2$ nadir, median (IQR, range)	93 (3, 75–97)	94 (3, 82–98)
SpO$_2$ <90%, median (IQR, range)	0 (0, 0–0.07)	0 (0, 0–0.001)

AHI = apnea-hypopnea index; IQR, interquartile range; ODI = oxygen desaturation index; SpO$_2$ = peripheral oxygen saturation.

Table 3—Associations between sleep position and breathing-characteristic estimated effects of sleep position.

	Nonsupine Position	Supine Position	P
AHI events	Ref	1.59	<.0001
ODI events	Ref	2.1	<.0001
SpO$_2$	Ref	−0.04	.4
SpO$_2$ nadir	Ref	−0.9	.006
SpO$_2$ <90%	Ref	0.0002	.04

AHI and ODI estimated effects were obtained from a mixed Poisson model for event counts and represent the supine-to-nonsupine ratio of events; the Poisson model was adjusted for time spent in each position and continuous breathing measures (SpO$_2$, SpO$_2$ nadir, SpO$_2$ <90%) obtained from a mixed linear model and represents their mean differences in supine versus nonsupine sleep positions. AHI = apnea-hypopnea index; ODI = oxygen desaturation index; SpO$_2$ = peripheral oxygen saturation.

stillbirth.[19–22] The supine position during sleep is also known to affect OSA severity in the general population, and positional therapy is often recommended when suitable.[23] However, the association between supine position during sleep and OSA severity during pregnancy has not been examined in depth. The present study findings demonstrated that women in the third trimester of pregnancy slept in a supine position about one-half of the time and that sleeping in a supine position was associated with more respiratory events, more oxygen desaturation events, and deeper nocturnal oxygen desaturations compared with the nonsupine position. They also showed that there were no differences in body position during sleep between women with OSA compared with those without OSA and that sleep position was not related to maternal BMI. In addition, no associations were found between sleeping in a supine position and perinatal outcomes.

Women in the third trimester of pregnancy in this cohort slept in a supine position almost one-half of the time. This finding is almost double the percentage of time reported by O'Brien and

Warland.[16] One possible explanation for these differences is that sleep studies in the current study were conducted in a relatively narrow period of time toward the end of pregnancy (gestational age of 33–36 weeks) compared with a much wider period of time (7–38 weeks) in their study. The tendency of women to sleep more on their back toward the end of pregnancy may be attributed to physiologic changes, for example, weight gain, increased abdominal size, or fluid shifts. Toward the end of pregnancy women are no longer comfortable to sleep in the prone position due to increased abdominal size and may shift to the lateral or supine position. In addition, the weight gain together with hormonal changes and the tendency of some women to spend more time lying down during the day may cause fluid shift to the upper part of the body and affect sleep-position practice. Another possible explanation for the discrepancy is that the women in our cohort were less obese/overweight and could comfortably spend more time on their back during sleep. However, no associations were found between body position during sleep and maternal BMI in our cohort and, unfortunately, no information on maternal BMI is available in the report by O'Brien and Warland.[16]

Supine sleep position has significant effects on maternal hemodynamics. Supine sleep position has been shown to be associated with a reduction in maternal cardiac output and lower limb blood flow and increased hypotension. These observations are largely secondary to aorto-caval compression by the

Table 4—Association between maternal supine sleep position and breathing in pregnant women.

| Maternal Parameters | Minimum Oxygen Saturation | | | | | |
| | Model 1: Unadjusted | | | Model 2: Adjusted | | |
	Regression Coefficient	SE	P	Regression Coefficient	SE	P
Supine position	−0.02	0.01	.01	−0.02	0.01	.02
BMI at enrollment	−0.22	0.05	<.01	−0.22	0.05	<.01
Current smoking	−1.35	0.9	.16	−1.60	0.9	.08

BMI = body mass index.

enlarging gravid uterus and therefore most pronounced at later gestations.[24]

In accordance with our hypothesis, we show that the supine sleep position was associated with more respiratory events and with more and deeper oxygen desaturations. Indeed, the percentage of time spent sleeping in the supine position predicted the SpO_2 nadir measurements in our cohort. These findings were supported by those of another recent study, which demonstrated improvements in maternal oxygenation and fetal heart rate decelerations following reduction in the time spent in the supine position during sleep[5]

The lack of any difference in the distribution of body positions during sleep among women with OSA and those without OSA was unexpected. Since sleeping in a supine position can compromise airway stability, we expected to find a higher proportion among the women who had pathologic/abnormal sleep-study results (AHI >5 events/h). Alternatively, women with OSA who experienced more disturbed sleep may tend to reduce the time spent on their back in order to improve their breathing and avoid choking or interruptions in breathing. With the progression of pregnancy and toward the end of it, the upward displacement of the diaphragm may lead to breathing difficulties and general discomfort, driving women to reduce their time in the supine position. However, these possibilities did not hold true in the current study, with our participants spending almost one-half of their time during sleep in the supine position. The fact that our cohort included relatively nonobese women with mild–moderate OSA is a possible explanation.

In addition, we believe that, similar to the general population, the population of pregnant women is likely heterogeneous. In the general OSA population, there are patients for whom there are close associations between a supine position during sleep and OSA severity, and who experience a substantial improvement following positional therapy. There are also patients in whom the association between body position during sleep and OSA severity is less apparent. Similarly, the negative effect of body position during sleep on breathing may also be variable among pregnant women

Maternal position can also affect the fetus. A study in awake, healthy, pregnant women in late-gestation pregnancy has shown that sleep position can affect fetal behavioral state and heart rate variability.[25] Specifically, fetal heart rate variability was reduced in the supine or semi-recumbent positions and the likelihood of fetal quiescence was increased and altering maternal position from supine to left lateral positions significantly increased fetal movements and improved fetal heart rate variability. Interestingly, the increased likelihood of fetal quiescence in the supine position found in the same study suggests that the fetus is adopting a low-oxygen-consuming state.[25] In the present study, we did not find any associations between sleeping in the supine position and any of the perinatal outcomes, including gestational age, birth weight, and Apgar score. Our cohort, however, was composed of healthy, nonobese, pregnant women with no pregnancy complications. It is possible that sleep position will play a significant role and negatively affect perinatal outcomes in higher-risk pregnancies such as obese women with severe OSA or in women with suboptimal placental function.

The strength of this study is the simultaneous implementation of objective assessment of breathing characteristics and body position during sleep in the home environment. Objective assessment of these measures decreases information bias and increases study validity. The inclusion of healthy women with no pregnancy complications that could influence either breathing or body position during sleep is an additional strength. One limitation of this study is that sleep was measured during only 1 night during the third trimester of pregnancy and the results may not represent the woman's characteristic sleep habits. Another limitation is that the cross-sectional study design does not provide the direction of association (cause and effect) between maternal breathing and body position. Body position during sleep may have an impact on breathing, and breathing problems may influence body position. We provided no information on neck circumference, which is a potential confounder in the relationship between lying in a supine position and disordered breathing during sleep.[26] Finally, the present cohort comprises a low-risk group of pregnant women. It is possible that sleep position may play a role in the association with adverse perinatal outcomes in higher-risk populations.

In summary, women in the third trimester of pregnancy with and without OSA spend a great proportion of time in a supine position during sleep. The supine position is associated with more respiratory events, more oxygen desaturation events, and deeper nocturnal oxygen desaturations. Maternal sleep position and OSA are potentially modifiable and treatable factors that have the potential for reducing poor pregnancy outcomes. Although this study did not find differences in sleep-position distribution between women with and without OSA or associations between supine sleep position and perinatal outcomes, our findings suggest that avoiding the supine sleep position in

the third trimester of pregnancy is likely to reduce AHI and improve breathing.

ABBREVIATIONS

AHI, apnea-hypopnea index
BMI, body mass index
ODI, oxygen desaturation index
OSA, obstructive sleep apnea
SpO$_2$, peripheral capillary oxygen saturation

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SUBMISSION & CORRESPONDENCE INFORMATION

DISCLOSURE STATEMENT