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Prospective Evaluation of Maternal Sleep Position Through 30 Weeks of Gestation and Adverse Pregnancy Outcomes

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Nulliparous Pregnancy Outcomes Study: Monitoring Mothers-to-be (NuMoM2b) study

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Abstract

Objective: To examine the relationship between prospectively assessed maternal sleep position and subsequent adverse pregnancy outcomes.

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Each author has confirmed compliance with the journal's requirements for authorship.

Methods: This was a secondary analysis of a prospective observational multicenter cohort study of nulliparous women with singleton gestations who were enrolled between October 2010 and May 2014. Participants had three study visits that were not part of clinical care. They prospectively completed in-depth sleep questionnaires between 6^0 and 13^6 weeks of gestation and 22^0 and 29^6 weeks of gestation, the first and third study visits (V1 and V3, respectively). A subset of women also underwent level 3 home sleep tests using the Embletta Gold device. The primary outcome was a composite of adverse pregnancy outcomes including stillbirth, small-for-gestational-age newborn, and gestational hypertensive disorders.

Results: Eight thousand seven-hundred six (of 10,038 total) women had data from at least one sleep questionnaire and for pregnancy outcomes, and they comprised the population for this analysis. The primary outcome occurred in 1,903 pregnancies (22%). There was no association between reported non-left lateral or supine sleep during the last week at V1 (aOR 1.00 (95% CI 0.89, 1.14)) or V3 (aOR 0.99 (95% CI 0.89, 1.11) and the composite or any individual outcome, except for an apparent protective effect for stillbirth at V3 (aOR 0.27 (95% CI 0.09, 0.75). Women with objectively measured supine sleep position for > 50% of the time were no more likely than those in the supine position   50% of the time to have the composite adverse outcome.

Conclusions: Going to sleep in the supine or right lateral position, as self-reported prior to the development of pregnancy outcome and objectively assessed through 30 weeks of gestation was not associated with an increased risk of stillbirth, small-for-gestational-age newborn, or gestational hypertensive disorders.

Precis:

Going to sleep in the supine or right lateral position through 30 weeks of gestation was not associated with adverse pregnancy outcomes.

Maternal sleep position has been associated with adverse pregnancy outcomes including stillbirth and fetal growth restriction.[1-5] Sleeping on the back or right side is thought to increase the risk for adverse perinatal outcomes due to compression of uterine blood vessels and decreased uterine blood flow.[6] Since sleep position is a potentially modifiable risk factor, these observations have prompted public health campaigns.[7] For example, the Tommy's charity has a program termed "The sleep on the side campaign."[7]

Although prior data suggest an association between supine sleep and adverse pregnancy outcomes, the validity of these findings remains uncertain. Prior studies have included small numbers of women and importantly, interviews regarding maternal sleep position were conducted after the stillbirth or other adverse pregnancy outcomes occurred.[1-5] This introduces the potential for considerable recall bias.

To address these prior methodological limitations, we performed a secondary analysis of data from the Nulliparous Pregnancy Outcomes Study: Monitoring Mothers-to-Be (nuMom2b). This study included prospective data collection during pregnancy at two time points regarding maternal sleep position, and provided detailed data regarding obstetric outcomes.

Methods

This was a secondary analysis of the nuMoM2b parent study and Sleep Disordered Breathing (SDB) sub-study, whose methods have been previously published.[8,9] The study is registered at ClinicalTrials.gov under . Briefly, the nuMoM2b parent study was conducted at eight clinical sites and managed by an independent Data Coordinating and Analysis Center. Inclusion criteria for the parent study were nulliparity (no prior delivery   20 weeks of gestation) and a viable singleton pregnancy at the time of screening between 6^0–13^6 weeks of gestation. Enrollment occurred between October 2010 and May 2014.

The study was approved by the Institutional Review Boards at each clinical site and the Data Coordinating Center, and all participants gave written informed consent. The observational cohort study involved three study visits that were not part of clinical care. These occurred at 6+0 to 13+6 weeks of gestation (V1), 16+0 to 21+6 weeks of gestation (V2), and 22+0 to 29+6 weeks of gestation (V3). At each study visit, participants underwent clinical assessment, obstetric sonogram, answered questionnaires and had biospecimens collected. At V1 and V3 (but not V2), one of the questionnaires included questions about sleep position and other sleep parameters.[8, 9] These questions were similar to those used in prior pregnancy and sleep position studies and showed modest correlation with objective sleep position in one study.[1,2,4,5,10] Specifically, women were asked what position they usually went to sleep in and woke up in during the last week and last night. Choices for sleep position included: on my left side mostly, on my right side mostly, both sides just as much, on my back mostly, on my front mostly, just as much on my side as on my front and back, and sitting up or propped up. A dichotomous sleep position variable was created by assigning a woman to the "left lateral sleep" category if she indicated that she slept "on my left side mostly"; otherwise she was assigned to "non-left lateral sleep". Similarly, a dichotomous variable for supine sleep was created by assigning a woman to "supine sleep" if she indicated she slept "on my back mostly". In order to group responses into four sleep position categories, if the woman selected "on my left side mostly", she was assigned to "left lateral sleep"; if she selected "on my right side mostly", she was assigned to "right lateral sleep"; if she selected "on my back mostly", she was assigned to "supine sleep"; otherwise she was assigned to "other sleep position".

The primary outcome for our analysis was a composite adverse pregnancy outcome including stillbirth, hypertensive disorders of pregnancy (mild, severe, or superimposed preeclampsia; eclampsia; or antepartum gestational hypertension), and small for gestational age (SGA) newborn. These were chosen since they all have been associated with abnormal placental function and most have been associated with non-left sided sleep.[1-5] Secondary outcomes were individual obstetric complications including stillbirth, hypertensive disorders of pregnancy, and SGA newborn. For all analyses, women with pregnancy losses prior to 20^0 weeks of gestation were excluded.

Precise and standard definitions of adverse pregnancy outcomes were used as previously described.[8,9,11,12] Medical record abstraction was performed by trained research personnel using a standardized protocol. Also, detailed chart abstraction including assessment of blood pressure severity, new-onset neurologic disturbances, epigastric pain or pulmonary edema,

and blood and urine laboratory results was done in all cases of hypertension or proteinuria by individuals blinded to sleep position.[11] Women with suspected hypertensive disorders of pregnancy who presented atypically, or were difficult to classify according to study criteria, were adjudicated by the principal investigators, and final classification was reached by consensus.

Descriptive statistics were used to characterize the study population by adverse pregnancy outcomes status (yes versus no). Chi-square tests assessed adverse pregnancy outcome status with characteristics that were categorical and analysis of variance F-tests were used for continuous measurements. Crude and adjusted odds ratios and 95% confidence intervals were calculated from univariate and multivariate logistic regression models to relate sleep position in early and mid-pregnancy (a time period that extends to 30 weeks of gestation, which includes the start of the third trimester) to adverse pregnancy outcomes. Adjustment covariates included maternal age (21, 22-35, and >35), body mass index (BMI; <25, 25 to <30, 30), and chronic hypertension (yes, no) in early pregnancy. Mid-pregnancy analyses were also adjusted for rate of weight gain from early pregnancy to mid-pregnancy. As a sensitivity analysis, propensity score methods were also used to further account for confounding and to reduce bias in estimates of adjusted odds ratios.[13]

The analysis *a priori* defined "left lateral sleep" versus "non-left lateral sleep" as the primary comparison of exposures since that is the sleep position recommended as most favorable for pregnancy. We also assessed supine sleep since this is the sleep position considered to be most unfavorable. Secondary analyses used different exposure categorizations: "left sided sleep" versus "supine sleep", "left sided sleep" versus "right-sided sleep", and combinations of sleep patterns.

An additional secondary analysis evaluated objective documentation of sleep position in a subset of participants who also underwent sleep disordered breathing assessment, using a level 3 home sleep test.[9,10] This sleep assessment took place immediately following V1 and V3 and used the Embletta-Gold device, which also recorded body position. For this analysis, a dichotomous sleep position variable was created based on whether the participant spent more than 50% of the time sleeping in the supine position.

All tests were performed at a nominal significance level of α=0.05, and all single degree of freedom tests were 2-sided. No correction was made for multiple comparisons. Analyses were conducted using SAS 9.3/9.4 software.

Results

Of the 10,038 women enrolled in the parent study, this analysis included the 8,706 with data available for pregnancy outcomes as well as responses from at least one sleep questionnaire (Figure 1). At baseline, women with unavailable data were slightly younger, more likely to be Hispanic or non-Hispanic black, more likely to have chronic hypertension, and less likely to have asthma than those with data available (Appendix 1, available online at http://links.lww.com/xxx). Of the 3,705 women enrolled in the sleep disordered breathing sub-

study, there were objectively measured data available regarding sleep position for 3,133 at V1 and 2,474 at V3.

A total of 1,903 women had at least one APO, with 178 having both SGA and hypertensive disorders, 8 with stillbirth and SGA, 3 with stillbirth and hypertensive disorders, and 2 with all 3 complications (Table 1). Women with adverse pregnancy outcomes had higher BMIs, were more likely to smoke, more likely to have chronic hypertension, pre-gestational diabetes, and kidney disease, more likely to be non-Hispanic black, and less likely to be non-Hispanic white than those without adverse pregnancy outcomes.

No self-reported sleep positions including either non-left lateral or supine were identified, either the night prior to or the week prior to the study visit, that were associated with the composite adverse pregnancy outcome (Table 2).

Propensity score methods were used to adjust the results relating non-left lateral position in the week prior to the study visit to the composite outcome for all variables in Table 1 (results not shown). Again, no association was found.

As with position at sleep onset, there was no association of self-reported sleep position upon awakening (including non-left lateral or supine sleep) the night or the week before the study visit with adverse pregnancy outcomes (Table 3).

There was no association between any self-reported sleep position including non-left lateral and supine sleep position and gestational hypertensive disorders or small for gestational age newborn (Table 4). Results were unchanged when SGA newborn was defined as weight < 5% for gestational age (data not shown). Propensity score methods were also used to adjust results relating non-left lateral position in the week prior to the study visit to individual adverse pregnancy outcomes of hypertensive disorders and small for gestational age newborn for all variables in Table 1 (results not shown). Again, no association was found. Similar results were obtained regarding self-reported sleep position upon waking up and individual adverse outcomes (data not shown).

Non-left lateral sleep in mid-pregnancy was associated with a decreased risk of stillbirth (5/4,667 (0.1%) versus 13/3,511 (0.4%); aOR 0.27; 95% CI 0.09, 0.75). Results of sensitivity analyses for the stillbirth outcome using propensity score matching were similar (aOR 0.28; 95% CI 0.09, 0.90). We did not analyze further subsets of sleep position and stillbirth due to the small number of stillbirths (N=18) that could be included in the analysis at V3. Although there were 40 women with stillbirth completing a V1 or V3 sleep questionnaire, only 10 were at   37 weeks gestation and 18 occurred at   24 weeks gestation.

The relationship between objectively measured sleep position and adverse outcomes was similar to that for self-reported sleep position (Table 5). Women with supine sleep position for > 50% of the time were no more likely than those in the supine position   50% of the time to have the composite adverse outcome. When other thresholds were explored, there was no relationship between increasing amounts of time spent in supine sleep and adverse outcomes (Appendix 2, available online at http://links.lww.com/xxx). There were too few

individuals with each individual outcome in this subset to allow for meaningful analysis of objective sleep position and individual adverse outcomes.

We also explored the relationship between self-report and objectively measured sleep position. There was modest correlation between subjectively reported and objectively assessed sleep position. For example, women who reported sleeping on their back were more likely to spend > 50% of time in objectively measured supine sleep than those who did not (60.7% versus 30.3% V1; 51.6% versus 48.4% V3).

Post hoc, we considered the odds ratios that could be detected with the sample sizes and frequencies of adverse pregnancy outcomes we had observed. Using a sample size of N=8000 participants, a significance level=0.05; power=0.80; a probability of non-left lateral sleep=0.57; and the probabilities of adverse pregnancy outcomes given left lateral sleep equal to 13% for hypertensive disorders of pregnancy, 10% for SGA, 0.4% for stillbirth, and 22% for the composite. We found that we could detect odds ratios of 1.2 for hypertensive disorders of pregnancy, 1.23 for SGA, 2.4 for stillbirth, and 1.2 for the composite. That is, our study was adequately powered to detect clinically meaningful odds ratios.

Discussion

Going to sleep in the supine or right lateral position was not associated with an increased risk of a composite outcome including stillbirth, small for gestational age newborn, and gestational hypertensive disorders compared to going to sleep in the left lateral position. This was true for sleep position during the last night or prior week in both early and mid-pregnancy. A null finding was also shown using objective data on sleep position in a subset of the cohort.

These results differ substantially from several prior studies. In a case-control study in New Zealand including 155 women with stillbirth and 310 controls, women who slept on their back or right side had an increased risk of late stillbirth (aOR 2.54 (95% CI 1.04 to 6.18) compared to those sleeping on their left side.[1] The absolute risk of late stillbirth for left side sleepers was 1.96/1,000 compared to 3.93/1,000 for non-left side sleepers.

Similar results were noted in a case-control study in Australia. Supine sleeping was associated with an aOR of 6.26 (95% CI 1.2 – 34) for late stillbirth in 103 women with stillbirth and 192 controls.[2] A cross sectional study of 232 women in Ghana noted an increased risk of stillbirth (OR 8.0; 95% CI 1.5 – 43.2) and low birth weight (OR 5.0; 95% CI 1.2 – 20.2) in women with supine sleeping compared to other sleep positions.[3] Sleep position was self-reported after delivery.[3] Another case-control study of 164 women with late stillbirth noted an aOR of 3.67 (95% CI 1.74, 7.78) for supine going to sleep position the night prior to stillbirth.[5] Finally, a recent multicenter case-control study in the U.K. including 291 third trimester stillbirths noted an aOR of 2.3 (95% CI 1.04, 5.11) in women going to sleep in the supine position.[4] The latter two studies utilized gestational age matched ongoing pregnancies as controls.

The major difference between these studies and the current one is the timing of ascertainment of sleep position. Each of these studies asked women about sleep position

after the stillbirth or other adverse outcome occurred, leaving the potential for bias. This is especially true in cases of stillbirth since many women may have heard or been told to "not sleep on their backs" during pregnancy. Although more recent studies attempted to reduce recall bias by using structured questionnaires with questions about many different factors, the potential for recall bias, perhaps linked to parental guilt is considerable. In contrast, our prospective cohort design allowed for ascertainment of sleep position prior to the occurrence of the pregnancy outcome. Other differences among investigations included populations studied (nulliparous versus multiparous), single versus serial assessment of sleep position, accuracy of gestational dating criteria, and timing in gestation of sleep assessment (late first and early third trimesters versus mid-late third trimester). Finally, we noted similar results using objective measures of sleep position in a subset of women.

It is proposed that supine sleep may compress the vena cava and aorta, potentially reducing venous return and ultimately, placental blood flow. Decreased maternal cardiac output, maternal hypotension, and reduced fetal oxygenation have been reported with supine and right-sided maternal position compared to left.[14-16] In addition, a recent study noted an increase in abnormal fetal behavioral states as assessed by fetal heart rate tracings in maternal supine or right lateral compared to left lateral position.[17] Thus, it is biologically plausible that supine or right-sided sleep could increase the risk of stillbirth or other adverse outcomes associated with decreased placental blood flow. Another factor is an increase in the risk for sleep disordered breathing in the supine position.[18] Sleep-disordered breathing also is associated with adverse pregnancy outcomes such as preeclampsia.[11]

Maternal sleep position is an attractive pathway for stillbirth and placental insufficiency, since it is a potentially modifiable risk factor for stillbirth and other adverse pregnancy outcomes. Accordingly, public health efforts and educational programs could lower the rate of adverse pregnancy outcomes in a manner similar to safe sleeping promotion and SIDS. Nonetheless, such efforts have a potential downside. Some women may have trouble sleeping on their left side and they cannot control movement during sleep. Even with careful messaging, there is potential to increase anxiety in women who wake up on their backs and guilt, shame and self-blame in women suffering adverse pregnancy outcomes such as stillbirth. There is even the potential for cost and harm if anxiety leads to unnecessary antenatal testing and false positive results. Thus, it is critical to be sure that the benefits outweigh risks prior to implementing widespread public health campaigns.

A limitation of our study was the relatively small number of stillbirths, especially in late pregnancy, which limited our ability to adequately assess confounding. Accordingly, we cannot definitively exclude an association between supine sleep and late stillbirth due to limited sample size. However, the direction of the signal was in the opposite direction, with non-left lateral sleepers actually having a statistically lower risk of stillbirth compared to left lateral sleepers. (It is unlikely that left sided sleep increases the risk for stillbirth and this observation is likely spurious owing to small numbers.) Also, we were unable to objectively document sleep position in all participants. Others have noted good but imperfect correlation between recalled and actual going to sleep position.[10,19,20] Two small studies of videotaped sleep reported correlations for sleep onset position and patient recall of 0.48 - 0.52.[10,19] An observational cohort study comparing self-recall and polysomnography reported sleep

position found significant correlation between perceived and objectively measured supine sleep (r-square = 0.63, P < 0.0001).[20] However, there was poor negative predictive value for self-report and supine sleep and estimates of supine sleep duration were inaccurate.[20] We also noted relatively modest correlation between self-reported and objective sleep position. Thus, future studies should aim to objectively assess sleep position and duration when possible. Our objective measurements also did not distinguish between left and right lateral positions.

Importantly, we did not assess sleep position in the last two months of pregnancy. This may be the most sensitive window for supine sleeping to adversely affect pregnancy. Accordingly, our data do not exclude a relationship between non-left lateral or supine sleep at the end of pregnancy and late stillbirth.

Our study also had numerous strengths. Prospective assessment of sleep position prior to delivery considerably reduces recall bias. In addition, our study has a relatively large sample size with considerable racial, ethnic, and geographic diversity. We also had excellent gestational dating criteria, granular data regarding participants, and rigorous ascertainment of pregnancy outcomes and assessment of sleep habits at two time points. Finally, we had objective assessment of sleep position in a large subset of pregnancies. Given the relative infrequency of stillbirth and considerable expense, it will be difficult to perform larger prospective studies of the relationship between sleep position and this adverse pregnancy outcome.

In summary, supine or non-left sided sleep through 30 weeks gestation was not associated with adverse pregnancy outcomes linked to decreased placental blood flow in a large prospective cohort. These data should provide reassurance to women regarding sleep position through 30 weeks gestation.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements:

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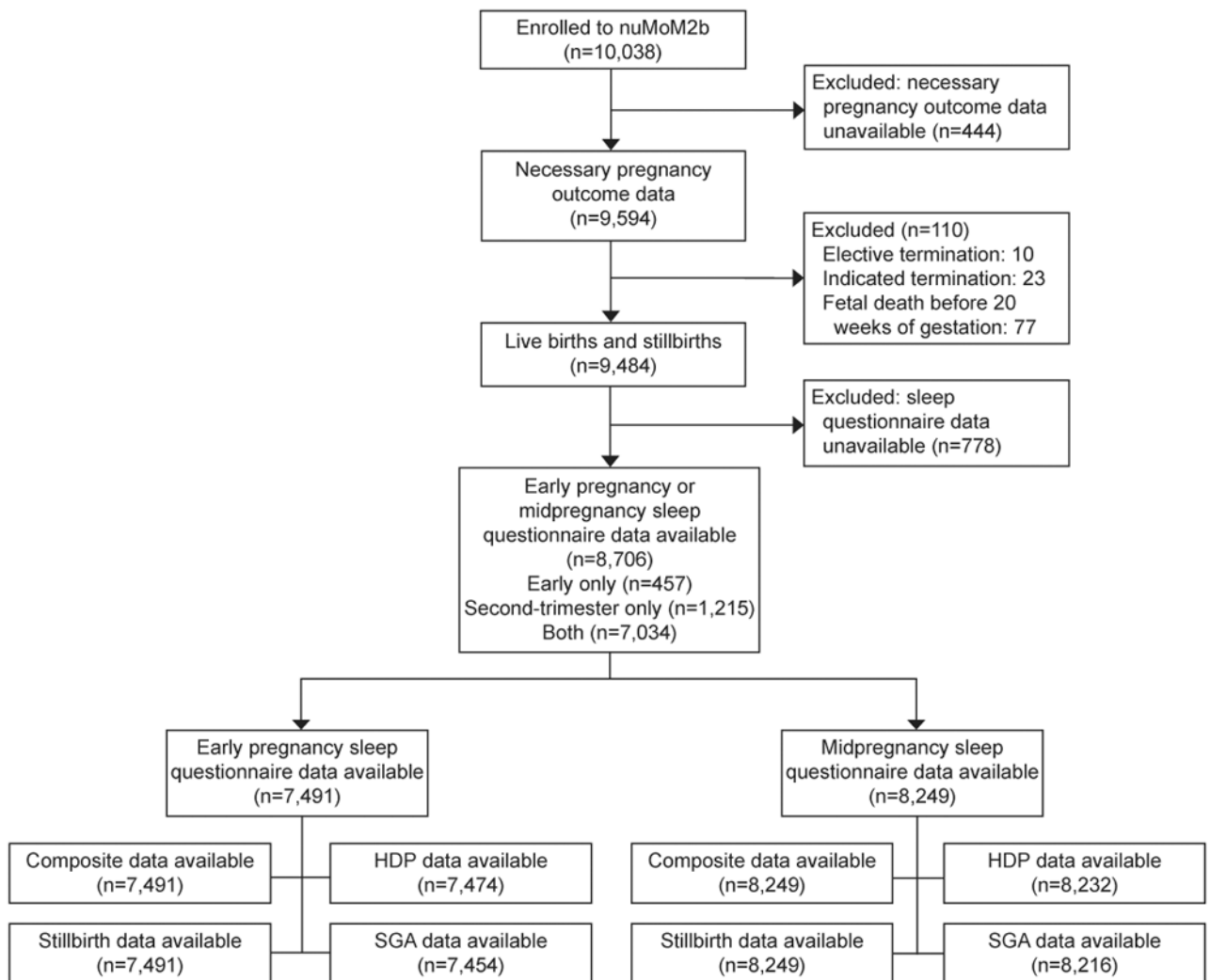
Figure 1:
Enrollment and inclusion in analysis. nuMoM2b, Nulliparous Pregnancy Outcomes Study: Monitoring Mothers-to-be. HDP, hypertensive disorders of pregnancy; SGA, small for gestational age.

Table 1

Baseline Characteristics of Participants Included in Early or Mid-Pregnancy Analyses By APO Status[a]

Baseline Characteristics	Overall (N = 8,706)	Women With APOs (N = 1,903)	Women Without APOs (N = 6,803)	p-value[b]
Maternal age, in years				
Mean (standard deviation)	27.1 (5.6)	26.7 (5.8)	27.2 (5.6)	< 0.01
Category: n (%)				< 0.01
13-21	1,752 (20.1)	436 (22.9)	1,316 (19.3)	
22-35	6,372 (73.2)	1,322 (69.5)	5,050 (74.2)	
>35	581 (6.7)	145 (7.6)	436 (6.4)	
Maternal race: n (%)				< 0.01
White Non-Hispanic	5,380 (61.8)	1,092 (57.4)	4,288 (63.0)	
Black Non-Hispanic	1,160 (13.3)	346 (18.2)	814 (12.0)	
Hispanic	1,388 (15.9)	276 (14.5)	1,112 (16.3)	
Asian	352 (4.0)	87 (4.6)	265 (3.9)	
Other	425 (4.9)	102 (5.4)	323 (4.7)	
BMI, in kg/m^2				
Mean (standard deviation)	26.3 (6.3)	27.7 (7.3)	25.9 (5.9)	< 0.01
Category: n (%)				< 0.01
<25	4,546 (53.1)	840 (44.8)	3,706 (55.4)	
25 to <30	2,133 (24.9)	487 (26.0)	1,646 (24.6)	
30	1,889 (22.0)	549 (29.3)	1,340 (20.0)	
Smoked during 3 months prior to pregnancy: n (%)				< 0.01
Yes	1,532 (17.6)	399 (21.0)	1,133 (16.7)	
No	7,170 (82.4)	1,504 (79.0)	5,666 (83.3)	
Gravidity: n (%)				0.21
1	6,482 (74.5)	1,421 (74.7)	5,061 (74.4)	
2	1,660 (19.1)	345 (18.1)	1,315 (19.3)	
3	563 (6.5)	137 (7.2)	426 (6.3)	
Chronic hypertension: n (%)				< 0.01
Yes	205 (2.4)	75 (3.9)	130 (1.9)	
No	8,481 (97.6)	1,826 (96.1)	6,655 (98.1)	
Pre-gestational diabetes: n (%)				< 0.01
Yes	137 (1.6)	55 (2.9)	82 (1.2)	
No	8,557 (98.4)	1,847 (97.1)	6,710 (98.8)	
Asthma: n (%)				0.19
Yes	1,106 (12.7)	259 (13.6)	847 (12.5)	
No	7,575 (87.3)	1,642 (86.4)	5,933 (87.5)	
Kidney disease: n (%)				0.01
Yes	56 (0.6)	20 (1.1)	36 (0.5)	
No	8,625 (99.4)	1,881 (98.9)	6,744 (99.5)	

Abbreviations: APO = adverse pregnancy outcome; BMI = body mass index

[a]Women who experienced any of the following APOs were included in the "Women With APOs" column: stillbirth, hypertensive disorder of pregnancy, or small-for-gestational-age fetus.

[b]p-values are shown for chi-square tests for APO status and the categorical baseline characteristics and from ANOVA F-tests for APO status and continuous baseline characteristics.

Table 2

Crude and Adjusted[1] Odds Ratios for Composite of Stillbirth, Small for Gestational Age, and Hypertensive Disorder of Pregnancy[2] According to Sleep Position When Going to Bed

Sleep Position Categories	Early Pregnancy (Visit 1)			Mid Pregnancy (Visit 3)		
	APO Composite n/N (%)	Crude OR (95% CI)	Adjusted OR (95% CI)	APO Composite n/N (%)	Crude OR (95% CI)	Adjusted OR (95% CI)
On Average, During the Last Week						
Left lateral (referent)	458/2079 (22.0)	1.00	1.00	751/3511 (21.4)	1.00	1.00
Non-left lateral (vs left lateral)	1187/5347 (22.2)	1.01 (0.89, 1.14)	1.00 (0.89, 1.14)	1006/4667 (21.6)	1.01 (0.91, 1.12)	0.99 (0.89, 1.11)
		p-value=0.87	*p-value=0.96*		*p-value=0.86*	*p-value=0.87*
Left lateral (referent)	458/2079 (22.0)	1.00	1.00	751/3511 (21.4)	1.00	1.00
Right lateral (vs left lateral)	292/1344 (21.7)	0.98 (0.83, 1.16)	0.98 (0.83, 1.16)	358/1618 (22.1)	1.04 (0.91, 1.20)	1.03 (0.89, 1.19)
Supine (vs left lateral)	136/670 (20.3)	0.90 (0.73, 1.12)	0.93 (0.75, 1.16)	55/280 (19.6)	0.90 (0.66, 1.22)	0.87 (0.63, 1.19)
Other position (vs left lateral)	759/3333 (22.8)	1.04 (0.91, 1.19)	1.03 (0.90, 1.17)	593/2769 (21.4)	1.00 (0.89, 1.13)	0.98 (0.87, 1.11)
		p-value=0.52	*p-value=0.82*		*p-value=0.81*	*p-value=0.78*
Last Night						
Left lateral (referent)	522/2343 (22.3)	1.00	1.00	785/3704 (21.2)	1.00	1.00
Non-left lateral (vs left lateral)	1109/5038 (22.0)	0.98 (0.88, 1.11)	0.97 (0.86, 1.10)	966/4438 (21.8)	1.03 (0.93, 1.15)	0.99 (0.89, 1.11)
		p-value=0.80	*p-value=0.65*		*p-value=0.53*	*p-value=0.91*
Left lateral (referent)	522/2343 (22.3)	1.00	1.00	785/3704 (21.2)	1.00	1.00
Right lateral (vs left lateral)	348/1646 (21.1)	0.94 (0.80, 1.09)	0.93 (0.79, 1.08)	423/1955 (21.6)	1.03 (0.90, 1.17)	1.00 (0.87, 1.14)
Supine (vs left lateral)	168/765 (22.0)	0.98 (0.81, 1.20)	1.00 (0.82, 1.22)	82/380 (21.6)	1.02 (0.79, 1.32)	0.96 (0.74, 1.26)
Other position (vs left lateral)	593/2627 (22.6)	1.02 (0.89, 1.16)	1.00 (0.87, 1.14)	461/2103 (21.9)	1.04 (0.92, 1.19)	1.00 (0.87, 1.14)
		p-value=0.74	*p-value=0.75*		*p-value=0.93*	*p-value=1.00*

[1] Early and mid-pregnancy adjusted for age, BMI and chronic hypertension as determined in early pregnancy. Mid-pregnancy also adjusted for rate of weight gain from early pregnancy to mid-pregnancy.

[2] Hypertensive disorder of pregnancy includes mild, severe, and superimposed preeclampsia and eclampsia, plus antepartum gestational hypertension.

Table 3

Crude and Adjusted [1] Odds Ratios for Composite of Stillbirth, Small for Gestational Age, and Hypertensive Disorder of Pregnancy [2] According to Sleep Position When Waking Up

Sleep Position Categories	Early Pregnancy (Visit 1)			Mid Pregnancy (Visit 3)		
	APO Composite n/N (%)	Crude OR (95% CI)	Adjusted OR (95% CI)	APO Composite n/N (%)	Crude OR (95% CI)	Adjusted OR (95% CI)
On Average, During the Last Week						
Left lateral (referent)	341/1496 (22.8)	1.00	1.00	463/2201 (21.0)	1.00	1.00
Non-left lateral (vs left lateral)	1252/5687 (22.0)	0.96 (0.83, 1.10)	0.95 (0.83, 1.09)	1251/5824 (21.5)	1.03 (0.91, 1.16)	1.03 (0.91, 1.17)
		p-value=0.52	p-value=0.47		p-value=0.67	p-value=0.60
Left lateral (referent)	341/1496 (22.8)	1.00	1.00	463/2201 (21.0)	1.00	1.00
Right lateral (vs left lateral)	280/1210 (23.1)	1.02 (0.85, 1.22)	0.99 (0.82, 1.19)	356/1612 (22.1)	1.06 (0.91, 1.24)	1.04 (0.89, 1.22)
Supine (vs left lateral)	311/1468 (21.2)	0.91 (0.77, 1.08)	0.93 (0.78, 1.11)	320/1474 (21.7)	1.04 (0.89, 1.22)	1.08 (0.91, 1.27)
Other position (vs left lateral)	661/3009 (22.0)	0.95 (0.82, 1.11)	0.95 (0.82, 1.10)	575/2738 (21.0)	1.00 (0.87, 1.15)	1.01 (0.87, 1.16)
		p-value=0.59	p-value=0.81		p-value=0.81	p-value=0.79
Last Night						
Left lateral (referent)	424/1981 (21.4)	1.00	1.00	578/2716 (21.3)	1.00	1.00
Non-left lateral (vs left lateral)	1164/5176 (22.5)	1.07 (0.94, 1.21)	1.08 (0.95, 1.22)	1141/5286 (21.6)	1.02 (0.91, 1.14)	1.01 (0.90, 1.14)
		p-value=0.32	p-value=0.26		p-value=0.75	p-value=0.80
Left lateral (referent)	424/1981 (21.4)	1.00	1.00	578/2716 (21.3)	1.00	1.00
Right lateral (vs left lateral)	409/1734 (23.6)	1.13 (0.97, 1.32)	1.14 (0.98, 1.34)	467/2186 (21.4)	1.00 (0.88, 1.15)	0.99 (0.86, 1.14)
Supine (vs left lateral)	344/1568 (21.9)	1.03 (0.88, 1.21)	1.05 (0.90, 1.24)	308/1421 (21.7)	1.02 (0.88, 1.20)	1.04 (0.89, 1.23)
Other position (vs left lateral)	411/1874 (21.9)	1.03 (0.89, 1.20)	1.03 (0.89, 1.21)	366/1679 (21.8)	1.03 (0.89, 1.20)	1.02 (0.88, 1.19)
		p-value=0.42	p-value=0.38		p-value=0.98	p-value=0.92

[1] Early and mid-pregnancy adjusted for age, BMI and chronic hypertension as determined in early pregnancy. Mid-pregnancy also adjusted for rate of weight gain from early pregnancy to mid-pregnancy.

[2] Hypertensive disorder of pregnancy includes mild, severe, and superimposed preeclampsia and eclampsia, plus antepartum gestational hypertension.

Table 4

Crude and Adjusted [1/] Odds Ratios for Individual Adverse Pregnancy Outcomes According to Sleep Position (Usual Position for Going to Sleep During the Last Week) in Mid-pregnancy

APO Outcome/ Sleep Position Categories	APO n/N (%)	Crude Odds Ratios		Adjusted Odds Ratios	
		Estimate (95% CI)	p-value	Estimate (95% CI)	p-value
Stillbirth					
Left lateral sleep (referent)	13/3511 (0.4)	1.00		1.00	
Non-left lateral sleep (versus left lateral sleep)	5/4667 (0.1)	0.29 (0.10, 0.81)	0.02	0.27 (0.09, 0.75)	0.01
Hypertensive disorder of pregnancy [2/]					
Left lateral sleep (referent)	464/3507 (13.2)	1.00		1.00	
Non-left lateral sleep (versus left lateral sleep)	592/4655 (12.7)	0.96 (0.84, 1.09)	0.49	0.92 (0.81, 1.06)	0.25
Left lateral sleep (referent)	464/3507 (13.2)	1.00		1.00	
Right lateral sleep (versus left lateral sleep)	207/1616 (12.8)	0.96 (0.81, 1.15)	0.52	0.94 (0.79, 1.13)	0.49
Supine sleep (versus left lateral sleep)	28/277 (10.1)	0.74 (0.49, 1.10)		0.75 (0.50, 1.13)	
Other sleep position (versus left lateral sleep)	357/2762 (12.9)	0.97 (0.84, 1.13)		0.93 (0.80, 1.09)	
Small for gestational age newborn					
Left lateral sleep (referent)	351/3493 (10.0)	1.00		1.00	
Non-left lateral sleep (versus left lateral sleep)	499/4653 (10.7)	1.08 (0.93, 1.24)	0.32	1.05 (0.90, 1.22)	0.52
Left lateral sleep (referent)	351/3493 (10.0)	1.00		1.00	
Right lateral sleep (versus left lateral sleep)	173/1614 (10.7)	1.07 (0.89, 1.30)	0.80	1.03 (0.85, 1.26)	0.90
Supine sleep (versus left lateral sleep)	31/280 (11.1)	1.11 (0.76, 1.64)		0.99 (0.65, 1.49)	
Other sleep position (versus left lateral sleep)	295/2759 (10.7)	1.07 (0.91, 1.26)		1.07 (0.90, 1.26)	

[1/] Adjusted for age, BMI and chronic hypertension as determined in early pregnancy and for rate of weight gain from early pregnancy to mid-pregnancy.

[2/] Hypertensive disorder of pregnancy includes mild, severe, and superimposed preeclampsia and eclampsia, plus antepartum gestational hypertension.

Table 5

Crude and Adjusted [1] Odds Ratios for Composite of Stillbirth, Small for Gestational Age, and Hypertensive Disorder of Pregnancy [2] According to Objectively Recorded Sleep Position (Percentage of Time in Supine Position)

Objectively Recorded Sleep Position Categories	APO Composite n/N (%)	Crude Odds Ratios		Adjusted Odds Ratios	
		Estimate (95% CI)	p-value	Estimate (95% CI)	p-value
Early Pregnancy (Visit 1)					
≤50% of time in supine position (referent)	457/2003 (22.8)	1.00		1.00	
> 50% of time in supine position (versus ≤ 50% of time)	220/1130 (19.5)	0.82 (0.68, 0.98)	0.03	0.87 (0.73, 1.05)	0.15
Mid-Pregnancy (Visit 3)					
≤50% of time in supine position (referent)	413/1973 (20.9)	1.00		1.00	
> 50% of time in supine position (versus ≤ 50% of time)	124/501 (24.8)	1.24 (0.99, 1.56)	0.06	1.24 (0.98, 1.57)	0.07

[1] Early and mid-pregnancy adjusted for age, BMI and chronic hypertension as determined in early pregnancy. Mid-pregnancy also adjusted for rate of weight gain from early pregnancy to mid-pregnancy.

[2] Hypertensive disorder of pregnancy includes mild, severe, and superimposed preeclampsia and eclampsia, plus antepartum gestational hypertension.