Published in final edited form as:
Int J Gynaecol Obstet. 2020 April ; 149(1): 82–87. doi:10.1002/ijgo.13096.

Effects of maternal sleep position on fetal and maternal heart rate patterns using overnight home fetal ECG recordings

Maristella Lucchini[1,*], **Ronald J. Wapner**[2], **Nhan-Chang Chia-Ling**[2], **Caroline Torres**[2], **Joel Yang**[1], **Ismee A. Williams**[3,4], **William P. Fifer**[1,3,5]

[1]Department of Psychiatry, Columbia University Medical Center, New York, NY, USA.

[2]Department of Obstetrics and Gynecology, Columbia University Medical Center, New York, NY, USA.

[3]Division of Developmental Neuroscience, New York State Psychiatric Institute, New York, NY, USA.

[4]Department of Pediatric Cardiology, Children's Hospital at Montefiore, Bronx, NY, USA.

[5]Department of Pediatrics, Columbia University Medical Center, New York, NY, USA.

Abstract

Objective—To assess the effects of maternal position on maternal and fetal heart rate and heart rate variability (HRV) in healthy late gestation pregnancies using non-invasive techniques during overnight studies.

Methods—In an observational study of women between 34 and 36 weeks of pregnancy conducted from September 1, 2013, to March 31, 2014, at Columbia University Medical Center, New York, US, maternal and fetal ECG recordings and position monitoring were undertaken through the night in the woman's own home. These data were used for time domain analyses of fetal and maternal heart rate and HRV.

Results—Forty-two women were recruited to the study which showed that maternal position affected maternal heart rate (MHR), with left side sleeping associated with lower heart rate (left vs right P=0.017, left vs supine P=0.027) and higher overall HRV (left vs right p=0.032). MHR showed significant overnight changes (P=0.032). No significant positional or overnight effects were observed in fetal heart rate patterns.

Conclusion—This study uniquely incorporated analyses on maternal and fetal physiology and extended the knowledge of effects of maternal overnight sleep position on MHR in the natural sleep environment.

[*]**CORRESPONDENCE:** Maristella Lucchini, 1051 Riverside Drive, Unit 40 New York, NY 10032, USA. ml3551@cumc.columbia.edu.

AUTHOR CONTRIBUTIONS
RJW, NC, and CT contributed to the conception and design of the study, and collection of the data. ML, JW, IAW, and WPF contributed to analysis of the data. ML and WPF contributed to revising the manuscript. All the authors contributed to the interpretation of data, drafting the manuscript, and approved the final version to be published.

CONFLICTS OF INTEREST
The authors have no conflicts of interest.

Keywords

Abdominal fetal ECG; Fetal autonomic control; Fetal sleep state; Heart rate variability; Maternal sleep position; Stillbirth

1 INTRODUCTION

Recent studies of late gestation stillbirth highlight the possible role of maternal sleep position on the risk of intrauterine death, with women who reported going to sleep on their back or right side more likely to experience a stillbirth. Physiological changes in pregnancy are dramatic and are intended to help the mother adjust to new metabolic needs, such as a consistent increase in blood volume and heart rate as well as reduced systemic vascular resistance, to support the demand for an increase in cardiac output [1,2]. External factors may complicate this adaptation process. For instance, during late pregnancy, uterine weight increases and this can lead to partial/complete occlusion of the inferior vena cava and lateral displacement of the sub-renal aorta in the supine position, affecting maternal hemodynamics and fetal oxygenation [3,4]. Supine position may also result in decreased vagal activity and increased cardiac sympathetic activity when compression of the vena cava, abdominal aorta, and the iliac arteries reduces venous return and cardiac output [5]. A healthy circulatory system during pregnancy is normally capable of adapting to these changes. However, latent and undiagnosed pathologies or prolonged exposure to risks may impair the cardiovascular response [6,7].

Previous studies showed that most women after 30 weeks of pregnancy sleep in a position that is not likely to produce aorto-caval compression (right/ left lateral) [8]. Nonetheless, reports on the percentage of mothers sleeping supine and the length of time spent in this position vary greatly [9]. A landmark study of stillbirths at 28 or more weeks of gestation at diagnosis in New Zealand found that women who reported going to sleep on their back or right side were more likely to experience a stillbirth [10]. Another case–control study from Australia reported that women who slept on their backs in late pregnancy were more likely to have a stillbirth [11]. A cross-sectional study in Ghana reported similar outcomes, with supine position associated with an increased risk for low birth weight and stillbirth [12]. The Midland and North of England Stillbirth Study also reported that going to sleep in the supine position significantly increased the risk of stillbirth [13].

This is particularly relevant in the context of the triple risk model proposed by Warland and Mitchell [14], which describes stillbirth as the outcome of interactions among: 1) maternal factors, such as age, body mass index (BMI, calculated as weight in kilograms divided by the square of height in meters), smoking, or alcohol consumption; 2) fetal and placental influences, such as intrauterine growth restriction (IUGR) or placental insufficiency; and 3) a stressor, such as veno-caval compression/occlusion while sleeping supine.

Late stillbirths are often unexplained, with no identified antecedent clinical risk factors. The absence of reliable markers of risk for stillbirth poses a significant knowledge gap. Further understanding of the etiology of these deaths with the aim to develop preventive strategies is warranted. Furthermore, studies have reported poor sleep quality in pregnancy, with later bedtimes, increased number and duration of night awakenings, and less total sleep [15]. This underscores the need for examination of the impact of sleep practices and habits during pregnancy.

The present study investigated the effects of maternal sleep position on maternal and fetal heart rate patterns using non-invasive overnight recordings collected from abdominal ECG. Maternal and fetal heart rate and heart rate variability (HRV), and maternal movement and position were recorded under normal sleep conditions at home during late pregnancy. More specifically, alterations in both maternal and fetal heart rate patterns were assessed as a function of maternal sleep position and fetal behavioral state.

The aim of the study was to assess if maternal sleep position during pregnancy had an effect on maternal and/or fetal autonomic regulation, as measured by HRV parameters.

2 MATERIALS AND METHODS

Population

The data presented in this manuscript come from an observational study carried out between September 1, 2013, and March 31, 2014. Patients who had participated in a sleep breathing study were approached by research personnel for inclusion in this ancillary observational study, carried out in the woman’s own home (New York, US). Inclusion criteria were: no previous pregnancy lasting 20 weeks or greater; maternal age greater than 13 years; and no fetal malformations or genetic abnormalities evident at the time of the study. Women who were using positive airway pressure therapy, those with severe asthma on continuous oral steroid therapy for more than 14 days, and those with conditions requiring oxygen supplementation were excluded from the study. Written informed consent was obtained from the participants, and the Institutional Review Board of the Columbia University Medical Center approved the study.

Acquisition set up

Data on fetal and maternal ECG, maternal respiration, and maternal sleep position (prone, supine, left, right) were collected throughout the night. Seven easily removable sensors were placed in standardized locations across the gravid abdomen. Pregnant women were sent home with electrodes applied and wearing two devices: the Embletta (Flaga Medical Devices, Reykjavik, Iceland) and the Monica AN24 fetal ECG monitor (Monica Healthcare System, Nottingham, UK). The Embletta was used to collect high resolution maternal ECG and position overnight, based on a tri-axial accelerometer. Monica AN24 recordings were started in the clinic while Embletta recordings were initiated by the mothers when they retired for the night. Study personnel retrieved the study equipment the following morning.

An important aspect was the time alignment between the Embletta and the Monica signals. Study personnel logged the start time of the Monica recording while mothers provided information on when they activated the Embletta recording. This information, paired with the visual inspection of the maternal heart rate (MHR) recordings obtained from both Embletta and Monica, was used to synchronize data from the two devices. Participants filled out questionnaires regarding their usual sleep position, the position they adopted when they went to bed on the night of the study, and the position they woke up in the following morning, to validate the data from the Embletta.

Heart rate analysis

The Monica device has built-in software to identify fetal and maternal QRS peaks from which fetal and maternal RR intervals were calculated. These tracings were used to perform heart rate analyses in 30-second epochs. Only epochs with a data quality above 70% were analyzed. Data quality was defined as number of accepted R waves divided by total number of R waves found in an epoch. Fetal RR intervals were deemed acceptable if greater than 300 millisecond and less than 667 ms and the absolute difference between consecutive RR intervals was less than 10%.

Mean maternal and fetal RR, standard deviation of normal-to-normal RR interval (SDNN), and root mean square of successive differences of RR intervals (RMSSD) were calculated for each segment. SDNN is the square root of variance: since the variance is equal to total power of spectral analysis, this parameter gives information summing all the cyclic contributions responsible for variability in the recording. RMSSD is the square root of the mean squared differences of successive RR intervals and quantifies short-term variability [16]. Maternal sleep position throughout the night was assessed with Embletta tracings and categorized as supine, left, right, and other. Anything other than these positions, for instance when the mother was moving or was partially tilted laterally, was discarded from the analysis.

Fetal behavioral states were coded following the method devised by Nijhuis et al. [17]. Fetal heart rate (FHR) pattern and movement are generally used to determine fetal behavioral state. In fetuses approaching term (>35 weeks of gestation), states can be assigned using FHR pattern in the absence of fetal movement and eye movements [18], as we did in this study. Fetuses present four different behavioral states: quiet sleep (1F), REM sleep (2F), quiet waking (3F), and active waking (4F). A minimum of 3 minutes in duration is necessary to define a state [17]. A state of quiescence with a stable heart rate pattern and low HRV is labeled 1F. A state of high HRV is labeled 2F. A state of quiescence with a stable heart rate pattern and low HRV is labeled 3F. A state of high HRV with long-lasting accelerations fused with tachycardia is labeled 4F. Two research assistants who were trained in fetal state assignment coded 15% of the data simultaneously in order to assess inter-rater reliability. The percentage of agreement was 83%, Cohen's κ=0.77. The remainder of the data were coded individually by either one of the coders. For problematic epochs, the scorers reviewed the observations together, blinded to the original scoring, and reached a consensus.

Parameters extracted both for mothers and fetuses from each epoch of the entire night were averaged based on position and fetal behavioral state. We discarded the first hour of recording from the analysis to exclude any period when the mothers were awake. From the literature we know that, on average, people take 15 minutes to fall asleep, but pregnant women take longer as a result of discomfort [15]. The first analysis performed focused on assessing the presence of overnight patterns in maternal and fetal heart rate parameters by comparing the first 2 hours of sleep with the last 2 hours. Secondly, the effects of positional changes on maternal and fetal heart rate parameters were evaluated.

Statistical analyses

Overnight patterns were tested with paired t-test analyses. Position changes were tested with paired t-tests, comparing left–right, left–supine, and right–supine to maximize the data available. All analyses were carried out in SPSS version 24 (IBM, Armonk, NY, USA). $P<0.05$ was considered statistically significant.

3 RESULTS

A total of 42 maternal/fetal dyads were enrolled in the study. Data collection took place between 34 weeks 0 days and 36 weeks 6 days of gestation. Table 1 summarizes maternal and infant characteristics.

Nineteen studies were excluded from the analysis for one or more of the following reasons: missing Monica or Embletta recording; Monica data quality <70%; inability to synchronize data from Monica and Embletta; and a total recording duration of <5 hours. Of 42 studies, 23 had reliable position and heart rate information throughout the night.

Mothers spent 1.09 % (0.06%−5.05%) of the night in the supine position, 31.44% (16.63% −38.10%) in the right, and 49.21% (39.39%−55.25%) in the left (values provided as median + interquartile range). They changed position 5.7±3.9 times per night (mean ± SD), excluding the first hour of recording. An example of an overnight recording can be seen in Figure 1. Maternal mean heart rate values for every 30 second epoch are shown in light gray, gray, black, and white. Colors indicate different sleeping positions. During the first 100 epochs (50 minutes) the mother is in an undetermined position and her heart rate is much higher than the rest of the recording, probably as a result of movement. At this time, the quality of the recording of the fetus is compromised and thus, behavioral state is classified as indeterminate (missing data points).

Effect of overnight pattern on maternal heart rate

To investigate overnight patterns, mean MHR in the second and third hours and in the last 2 hours of the night in the same position were compared. Results showed an average decrease of 1.61±4.63 beats per minute overnight (mean ± SD). Additionally, HRV increased during the night, with increases in SDNN of 4.44±9.31 millisecond and RMSSD of 7.35±12.27 millisecond (mean ± SD). Within-subject comparisons (paired t-tests) showed that heart rate and HRV change significantly during the night (mean heart rate $P<0.032$, SDNN $P<0.004$, RMSSD $P=0.001$).

Fetal data did not show significant overnight differences, but sample size was limited as repeated measures required common behavioral states in both the first and last 2 hours of the collection.

Table 2 reports all the data for fetal and maternal parameters.

Effect of fetal behavioral states on fetal heart rate

Analysis of fetal behavioral state showed that mean FHR and SDNN were significantly different (P=0.006, P<0.001 respectively) between 1F and 2F, but no difference was found in RMSSD.

Figure 2 shows mean and SD values for the three parameters in the two behavioral states.

Effect of position on maternal and fetal heart rate

Given differences by time of night in MHR, we separately analyzed the effects of position in the first and last hours of sleep. There was an effect of position on maternal cardiovascular activity. Table 3 presents measures of MHR by position and time of the night. These data showed overall average values across participants. However, all statistical comparisons were computed using within-subject repeated analyses.

In the first 2 hours, results from the paired t-test showed that mean MHR in left position was significantly lower than in right and in supine (P=0.017, P=0.027 respectively), but there was no difference between supine and right. SDNN was also significantly different between left and right (P=0.032), with left having higher values. In the last 2 hours of the night, values of mean MHR were trending in the same direction of the first 2 hours, but individual variability was very high and none of the tests reached significance, except for RMSSD which was significantly higher in left than in right position (P=0.035).

Position effects were not observed in FHR patterns, though there were relatively few fetuses who had data in the same behavioral state and the same maternal position for the time windows analyzed.

4 DISCUSSION

Recently, multiple studies reported an association between maternal sleep position in late pregnancy and the risk of stillbirth [10–12]. Sleep position, compared with other risk factors, such as elevated BMI or advanced maternal age, is modifiable and thus offers an approach for clinical research in stillbirth prevention [19]. Understanding the exact mechanisms underlying the effect of maternal sleep position both on the mother and the fetus could help interpret epidemiological findings and guide interventions [20].

Previous studies have addressed the effects of position on maternal hemodynamics in clinical settings [4,21]. Other studies have performed overnight recording, but focused on the effect of maternal position on FHR and fetal sleep [22]. To our knowledge, the present study was the first to incorporate both maternal and fetal physiology. The study results extend the knowledge of effects of position during overnight sleep on MHR, showing in the natural sleep environment higher MHR in supine and right postion compared to left. No effect of maternal position was observed in the fetus in our limited sample. Given that we had to assign one of four established fetal behavioral states, as well as maternal sleep position, to each epoch of recorded FHR data, the resulting numbers of data points were limited and were not sufficiently powered to detect potentially clinically important effects of maternal position on FHR. Additionally, while a robust overnight pattern in MHR was identified, this was not evident for FHR. As FHR is altered by behavioral state, data from more women with both early and late night epochs in the same behavioral state may be needed for evidence of an overnight rhythm to emerge. In one study, diurnal and overnight rhythms were observed, but in only 30% of the fetuses [23]. It is likely that FHR patterns are more dominated by rest–activity cycles (60–90 minutes) rather than ultradian and diurnal rhythms observed in adults, that may emerge around 4 months of age [24].

No effect of maternal position on FHR was reported in a study by Ibrahim et al. [21]. Stone et al. looked at the effect of maternal position on fetal behavioral state in the controlled setting of the laboratory [22] as well as in the home [25]. These investigators reported that, compared with the left side, FHR during supine position was slightly increased, and that both right and supine were associated with reduced SDNN, whereas only supine was associated with decreased RMSSD [22,25].

The present study did have some limitations, including the identification of position using the Embletta system rather than with video monitoring. This choice was made in the interest of minimizing invasiveness with respect to privacy concerns and participant comfort. Planned future studies will incorporate new devices, which are more reliable and less burdensome, to collect data on sleep position and maternal physiology at home. Another limitation was that, due to the natural sleep setting, the number of hours of sleep ranged from 5.6 to 9.5 hours.

In conclusion, sleep position and time of night strongly influenced maternal, but not fetal, heart rate patterns in the home setting. The interactive influences of maternal sleep position, overnight rhythms, and fetal behavioral state warrant further investigation and may contribute to our understanding of mechanisms underlying fetal well-being and risk for stillbirth.

ACKNOWLEDGMENTS

Research reported in this publication was supported by the Sackler Institute for Developmental Psychobiology at Columbia University and the Eunice Kennedy Shriver National Institute of Child Health and Human Development of the National Institutes of Health under award numbers U01HD055155 and U10HD063047. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

REFERENCES

1. Borton C, Tidy C. Physiological Changes In Pregnancy. J Soc Gynecol Invest. 2004;11:342–53.
2. Robson SC, Hunter S, Boys RJ, Dunlop W. Serial study of factors influencing changes in cardiac output during human pregnancy. Am J Physiol Hear Circ Physiol. 1989;256(4):H1060–5.
3. Humphries A, Mirjalili SA, Tarr GP, Thompson JMD, Humphries A, Mirjalili SA, et al. The effect of supine positioning on maternal hemodynamics during late pregnancy. J Fetal Matern Neonatal Med. 2019;32(23):3923–30.
4. Khatib N, Weiner Z, Beloosesky R, Vitner D, Thaler I. The effect of maternal supine position on umbilical and cerebral blood flow indices. Eur J Obstet Gynecol. 2014;175:112–4.
5. Kuo CD, Chen GY, Yang MJ, Tsai YS. The effect of position on autonomic nervous activity in late pregnancy. Anaesthesia. 1997;52(12):1161–5. [PubMed: 9485969]
6. Sattar N, Greer IA. Pregnancy complications and maternal cardiovascular risk: opportunities for intervention and screening? BMJ. 2002;325:157–60. [PubMed: 12130616]

7. Yogev Y, Visser GHA. Obesity, gestational diabetes and pregnancy outcome. Semin Fetal Neonatal Med. 2009;14:77–84. [PubMed: 18926784]
8. Mills GH, Chaffe AG. Sleeping positions adopted by pregnant women of more than 30 weeks gestation. Anaesthesia. 1994;49(3):249–50. [PubMed: 8147522]
9. O'Brien LM, Warland J. Typical sleep positions in pregnant women. Early Hum Dev. 2014;90(6):315–7. [PubMed: 24661447]
10. Stacey T, Thompson JMD, Mitchell EA, Ekeroma AJ, Zuccollo JM, McCowan LME. Association between maternal sleep practices and risk of late stillbirth: a case-control study. BMJ. 2011;342:d3403. [PubMed: 21673002]
11. Gordon A, Raynes-Greenow C, Bond D, Morris J, Rawlinson W, Jeffery H. Sleep Position, Fetal Growth Restriction, and Late-Pregnancy Stillbirth. Obstet Gynecol. 2015;125(2):347–55. [PubMed: 25568999]
12. Owusu JT, Anderson FJ, Coleman J, et al. Association of maternal sleep practices with pre-eclampsia, low birth weight, and stillbirth among Ghanaian women. Int J Gynecol Obstet. 2013;121(3):261–5.
13. Heazell AEP, Li M, Budd J, et al. Association between maternal sleep practices and late stillbirth – findings from a stillbirth case-control study. BJOG An Int J Obstet Gynaecol. 2018;125(2):254–62.
14. Warland J, Mitchell EA. A triple risk model for unexplained late stillbirth. BMC Pregnancy Childbirth. 2014;14(1):142. [PubMed: 24731396]
15. Mindell JA, Cook RA, Nikolovski J. Sleep patterns and sleep disturbances across pregnancy. Sleep Med. 2015;16(4):483–8. [PubMed: 25666847]
16. Task Force of the European Society of Cardiology. Heart Rate Variability. Standards of measurement, physiological interpretation and clinical use. Circulation. 1996;93(5):1043–65. [PubMed: 8598068]
17. Nijhuis JG, Prechtl HF, Martin CB, Bots RS. Are there behavioral states in the human fetus? Early Hum Dev. 1982;6(2):177–95. [PubMed: 7094856]
18. van Laar JO, Peters CHL, Vullings R, Houterman S, Oei SG. Power spectrum analysis of fetal heart rate variability at near term and post term gestation during active sleep and quiet sleep. Early Hum Dev. 2009;85(12):795–8. [PubMed: 19931326]
19. Warland J, Dorrian J, Kember AJ, et al. Modifying Maternal Sleep Position in Late Pregnancy Through Positional Therapy : A Feasibility Study. 2018; 14(8):1387–97.
20. Kember AJ, Scott HM, Brien LMO, et al. Modifying maternal sleep position in the third trimester of pregnancy with positional therapy : a randomised pilot trial. BMJ Open. 2018;8(8):e020256.
21. Ibrahim S, Jarefors E, Nel DG, Vollmer L, Groenewald CA, Odendaal HJ. Effect of maternal position and uterine activity on periodic maternal heart rate changes before elective cesarean section at term. Acta Obstet Gynecol Scand. 2015;94(12):1359–66. [PubMed: 26335140]
22. Stone PR, Burgess W, Mcintyre JPR, et al. Effect of maternal position on fetal behavioural state and heart rate variability in healthy late gestation pregnancy. J Physiol. 2017;595(4):1213–21. [PubMed: 27871127]
23. Lunshof S, Boer K, Wolf H, van Hoffen G. Fetal and maternal diurnal rhythms during the third trimester of normal pregnancy : Outcomes of computerized analysis of continuous twenty-four-hour fetal heart rate recordings. 1998;178(2):247–54.
24. Massin MM, Maeyns K, Withofs N, Ravet F, Gérard P. Circadian rhythm of heart rate and heart rate variability. Arch Dis Child. 2000;83(2):179–82. [PubMed: 10906034]
25. Stone PR, Burgess W, Mcintyre J, et al. An investigation of fetal behavioural states during maternal sleep in healthy late gestation pregnancy : an observational study. J Physiol. 2017;595(24):7441–50. [PubMed: 29023736]

SYNOPSIS

The study showed the effects of maternal position on maternal heart rate patterns and ultradian rhythms. Significant associations were not observed in our fetal recordings.

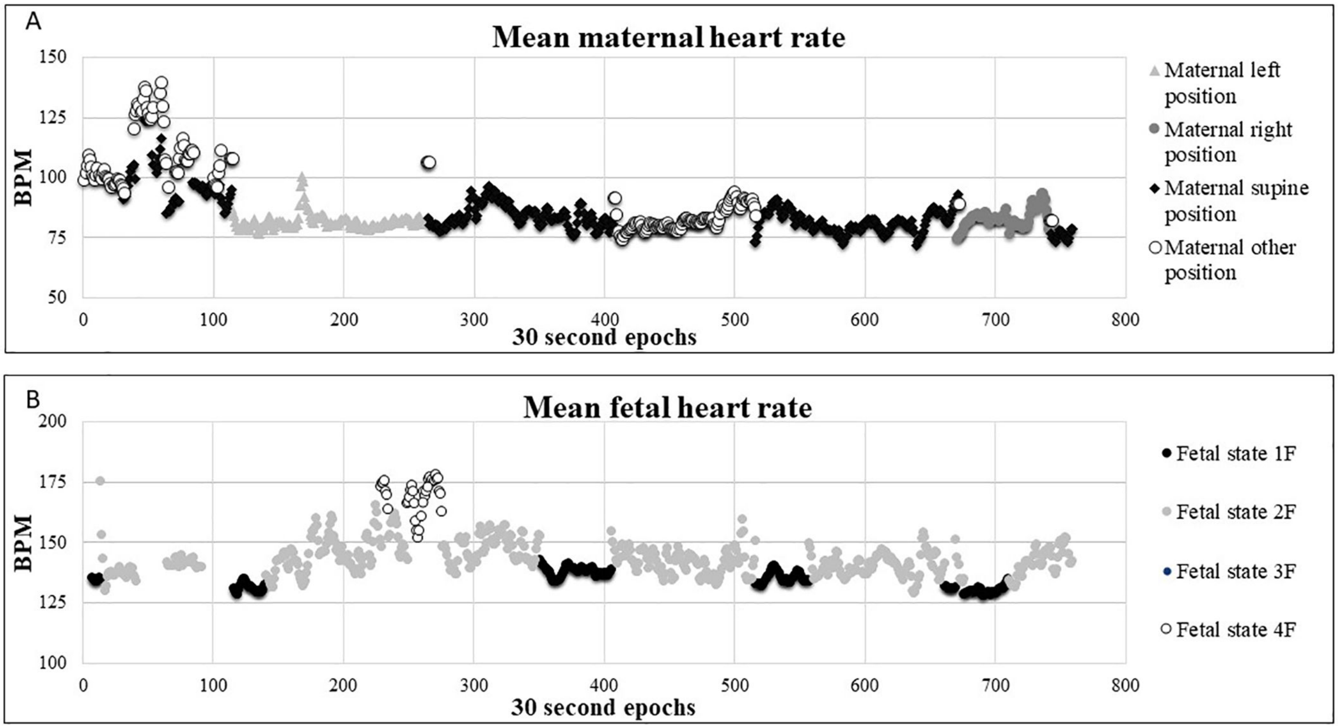

Figure 1.

An example of an overnight recording both for maternal (above) and fetal (below) mean heart rate. In panel A, maternal mean heart rate values for every 30 second epoch are shown. In panel B, fetal mean HR values for every 30 second epoch are shown.

Abbreviation: BPM, beats per minute.

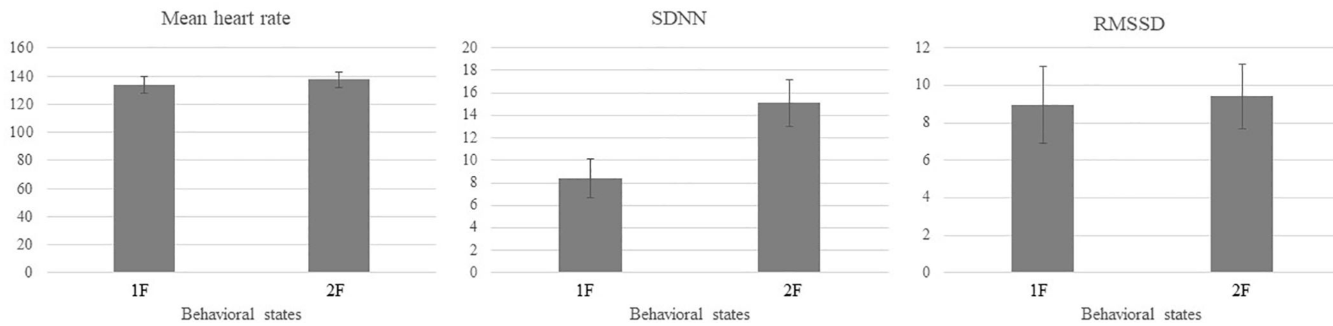

Figure 2.

Mean and SD values for mean heart rate, SDNN, and RMSSD parameters for fetal heart rare for behavioral states F1 and F2 are shown.

Abbreviations: RMSSD, root mean square of successive differences of RR intervals; SDNN, standard deviation of normal-to-normal RR interval.

Table 1

Demographics.

Maternal characteristics	
Age, y (mean±SD)	29.5±4.5
BMI at recruitment (mean±SD)	26.6±6.3
Weeks of pregnancy at assessment (mean±SD)	34.8±0.9
Race (%)	
Hispanic	35
White	65
Pre-eclampsia, n	1
Diabetic (gestational diabetes), n	1
Hypertensive, n	3
Fetal sex, n (male)	11/11[a]

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters).

[a]Information on sex for one infant was missing.

Table 2

Mean and SD values for maternal and fetal heart rate, SDNN, and RMSSD by behavioral state and time of the night.

	First 2 hours						**Last 2 hours**					
	Maternal											
	Heart rate		**SDNN**		**RMSSD**		**Heart rate**		**SDNN**		**RMSSD**	
Mean	79.18		31.74		22.42		77.90		36.98		31.94	
SD	9.66		10.40		9.12		10.79		16.60		19.21	
	Fetal											
Fetal state	1F	2F	1F	2F	1F	2F	1F	2F	1F	2F	1F	2F
Mean	136.30	138.30	7.40	15.46	7.55	9.16	133.10	137.10	7.54	14.59	7.73	9.05
SD	10.63	5.67	1.29	2.95	1.78	1.89	5.42	5.47	1.59	2.35	1.89	1.87

Abbreviations: RMSSD, root mean square of successive differences of RR intervals; SDNN, standard deviation of normal-to-normal RR intervals.

Table 3

Maternal and fetal heart rate variability measures by sleep position, time of the night and fetal behavioral state.

Maternal HRV measures by sleep position and time of the night				
	Position	**Mean heart rate**	**SDNN**	**RMSSD**
First 2 hours	**Left**	78.2±9.9	30.6±8.7	22.8±9.4
	Right	85.4±7.0	26.3±7.2	20.9±8.7
	Supine	84.8±13.7	33.4±11.4	17.7±5.8
Last 2 hours	**Left**	75.9±11.0	29.1±7.0	26.4±13.5
	Right	81.7± 8.1	27.8±8.3	19.0±6.1
	Supine	80.3±13.3	36.1±15.3	21.4±8.6
Fetal HRV measures by sleep position and sleep state				
Sleep state	**Position**	**Mean heart rate**	**SDNN**	**RMSSD**
1F [a]	**Left**	135.3±5.5	7.6±1.3	8.5±1.7
	Right	131.5±5.6	9.4±1.7	9.5±2.4
	Supine	n/a	n/a	n/a
2F [b]	**Left**	136.9±5.5	14.9±2.1	9.7±2.2
	Right	136.7±5.1	15.2±1.8	9.5±1.1
	Supine	139.6±5.7	15.1±2.6	8.8±1.1

Abbreviations: HRV, heart rate variability; RMSSD, root mean square of successive differences of RR intervals; SDNN, standard deviation of normal-to-normal RR intervals.

Values given as mean ± SD unless indicated otherwise.

[a] Quiet sleep.

[b] REM sleep.