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CLINICAL ARTICLE

Obstetrics

Sleep-disordered breathing and pregnancy outcomes: The impact of maternal oxygen saturation

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Abstract

Objective: To investigate pathological associations between sleep-disordered breathing (SDB) and pregnancy outcomes.

Methods: From May 2016 to September 2019, obese women during their uncomplicated singleton pregnancies underwent screening sleep questionnaires, oxygen saturation monitoring, and, in proper cases, complete overnight polysomnography. Their medical records were also recorded.

Results: In all, 112 pregnant women were included in the study cohort; 44 showed an oxygen desaturation index ≥10, and their newborns had a significantly higher rate of congenital abnormalities and respiratory distress syndrome compared with the women with normal pulse oximetry. Stepwise multivariate regression analysis showed that basal oxygen saturation was independently associated with the occurrence of fetal growth restriction.

Conclusion: Among obese pregnant women, the rate of congenital abnormalities is higher in the ones with altered pulse oximetry. Maternal basal oxygen saturation in the first trimester of pregnancy predicts fetal growth restriction independently of maternal age, ethnicity, body mass index, gravidity, and hypertensive disorders of pregnancy.

KEYWORDS
nocturnal pulse oximetry, obesity, obstructive sleep apnea-hypopnea syndrome, pregnancy, sleep-disorder screening questionnaires, sleep-disordered breathing

1 | INTRODUCTION

Sleep disorders are a spectrum of increasingly severe respiratory abnormalities, from loud snoring to obstructive sleep apnea-hypopnea syndrome (OSAHS), arising from partial or complete upper airway obstruction and impaired airflow and gas exchange. OSAHS is characterized by repeated upper airway obstruction during sleep that resolves with microarousals but results in poor sleep quality, intermitted hypoxemia, and hypercapnia. Although sleep-disordered breathing (SDB) has frequently been underdiagnosed, its prevalence in women is increasing along with maternal body mass index (BMI, calculated as weight in kilograms divided by the square of height in

meters) and other comorbidities. The interest in pregnancy sleep disorders increased with the rising obesity rate in the obstetric population. Moreover, it is well known that pregnancy predisposes women to develop or worsen OSAHS due to pregnancy-induced physiological changes in the respiratory system, including mucosal hyperemia, narrowing of the oropharyngeal diameter, decreased functional residual capacity, and higher oxygen consumption. Up to one-third of pregnant women report snoring in the third trimester.[1] Obesity and maternal age are consistent and independent risk factors of gestational OSAHS.[2] Among obese women, the rate of OSAHS is about 15%–20%, suggesting that a high proportion of women are entering pregnancy affected by this condition. Facco et al.[3] reported an OSAHS prevalence in the high-risk pregnancy population (e.g., obesity, chronic hypertension, pre-gestational diabetes, history of pre-eclampsia, and twin pregnancy) of 30% and 47% in the first and third trimesters, respectively.[3] Some evidence suggests that OSAHS exposes pregnant women to a higher risk of adverse events, including increased length of hospitalization, hypertensive disorders of pregnancy,[4] gestational diabetes,[5] congestive heart failure, and pulmonary embolism,[6] as well as fetal growth restriction (FGR), stillbirth, and preterm birth.[7]

Indeed, data from the general population have linked OSAHS with cardiovascular disorders. Bourjeily et al.[8] recently demonstrated a higher risk of congenital anomalies and peripartum resuscitation in babies from mothers with OSAHS. As a result of air flow limitation, arousals, and intermittent hypoxemia, OSAHS may induce an increase in sympathetic drive activity, oxidative stress, and endothelial dysfunction, thus impacting placental function, leading to hypoxia and altered levels of placenta-secreted markers.[9–11] By contrast, some pregnancy-related changes, such as preference for the lateral sleep position and the respiratory rate increase due to hormonal changes, may be protective. The impact of OSAHS on both the mother and her baby prompted us to assess targeted screening and interventions in the high-risk population. Based on several preliminary studies, sleep disturbances may impact fetal growth and well-being.[12–14] As the results on this topic are inconsistent, this area warrants further research. Therefore, we consider it essential, both diagnostically and preventively, to characterize the impact of decreased maternal oxygenation, mainly due to the obesity condition placing pregnant patients at higher risk of OSAHS development on pregnancy outcomes. As such, this study aims to evaluate the incidence of altered nocturnal pulse oximetry in obese pregnant women and test the association between altered nocturnal pulse oximetry and adverse perinatal outcomes.

2 | MATERIALS AND METHODS

This is a single-center study in compliance with the 1975 Declaration of Helsinki, approved by the Medical Ethics Committee of Brescia (ID no. 4165) and conducted according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[15]

Between May 2016 and September 2019, all women admitted to the Maternal-Fetal Medicine Unit of the Department of Obstetrics and Gynecology, ASST-Spedali Civili di Brescia & University of Brescia, Italy, for an outpatient assessment of their obesity were consecutively enrolled. Participants gave their written informed consent. Demographic and clinical data were collected from obstetric charts. Women were included if they had evidence of all the following conditions: pre-pregnancy BMI ≥30, singleton gestation, delivery at our obstetrics unit, and nocturnal pulse oximetry performed during pregnancy. The study cohort was strictly selected according to the following exclusion criteria: multiple pregnancies, pre-pregnancy BMI <30, and delivery in other hospitals.

Patients underwent screening questionnaires for sleepiness (Berlin, Epworth, and Swift questionnaires) and nocturnal pulse oximetry using an oxygen saturation monitor (NONIN WristOx2 3150; Nonin Medical Inc.). The screening questionnaires are developed and validated in the non-pregnant population, and in the current literature, the reported sensitivities and specificities are 36%–39% and 68%–77%, respectively.[16–19] Records obtained from nocturnal pulse oximetry were analyzed through the nVISION Data Management Software from Nonin Medical Inc. to formulate oximetry reports which were analyzed at the Sleep Respiratory Disease Outpatient Clinic of the Respiratory Medicine Unit, ASST-Spedali Civili di Brescia & University of Brescia. Each report showed the following data: basal oxygen saturation, total desaturation events, number of events per hour (oxygen desaturation index [ODI]), duration of events, average desaturation, and Nadir. Patients with positive nocturnal pulse oximetry were asked to perform polysomnography. Patients with an ODI equal to or greater than 10 were considered to be at OSAHS-related risk. In addition, patients at 21 weeks (or less) of pregnancy with an ODI greater than 5 were considered worthy of further investigation. A full-night unattended respiratory polysomnography was performed for each patient with positive nocturnal pulse oximetry. A specialized polysomnography technician connected the device to the patients. The polysomnography recording montage consisted of a nasal cannula, thoracic and abdominal respiratory effort bands, body position sensor, pulse oximetry, and snore sensor. Patients were taught how to disconnect the device, which was retrieved by the same technician the following day, and keep a sleep diary. Two portable diagnostic sleep recorders were used to screen the sleep apnea: Embletta MPR from Embla Systems Inc (now Natus) and Somtè 234gm from Somtè Compumedics. Records were first analyzed through the manufacturer-dedicated software—RemLogic-E v-3.4.1 and Somtè v-2.10 for Embletta MPR and Somtè 234gm, respectively—and then manually checked by the investigator for artifact removal and final validation. The polysomnography report showed the following data: total recording time, total sleep time, Apnea-Hypopnea Index (AHI), ODI, average desaturation drop, average SpO_2, minimum SpO_2, and number of snoring events.

Maternal comorbidities (e.g., chronic hypertension, diabetes mellitus, autoimmune disorders, thyroid and renal diseases) and pregnancy complications (e.g., hypertensive disorders of pregnancy, gestational diabetes, FGR, intrahepatic cholestasis, and preterm

birth) were investigated as well as the delivery mode, postpartum complications, and perinatal outcomes (e.g., gestational age at birth, birth weight, Apgar score, umbilical artery pH, admission to the neonatal intensive care unit [NICU], respiratory distress, malformations, and infections).

2.1 | Statistical analysis

After Levene's test for homoscedasticity, independent-samples Welch *t*-test was performed to analyze the difference between means for continuous variables. Continuous variables were tested visually for normality using Q-Q plots and were expressed as mean ± SD, while categorical variables were expressed as frequency (*n*) and percentage of the sample. The χ^2 test was used to assess differences between proportions. Multivariate regression analysis using the 'enter' method was performed to assess the association between basal oxygen saturation, the total number of desaturation events, ODI, maternal age, BMI at test time, gravidity, ethnicity, and hypertensive disorders of pregnancy as dependent variables, and FGR or congenital abnormalities as independent variables. Statistical analysis was performed using IBM SPSS Statistics 20 for Windows, version 20.0 (IBM Corp., Armonk, NY, USA). All values were two-tailed, and statistical significance was set at $P < 0.05$.

3 | RESULTS

We consecutively enrolled 112 obese women with a singleton pregnancy between May 2016 and September 2019. All women were screened for OSAHS through three screening questionnaires (Berlin, Epworth, and Swift) to assess sleepiness snoring, and apnea. Among these, 44/112 (39.3%) showed a pulse oximetry trace suggestive of nocturnal oxygen desaturations (positive pulse oximetry, group 1), while 68/112 (60.7%) had a normal trace (negative pulse oximetry, group 2). Among patients included in group 2, 34/68 women (50.0%) underwent nocturnal polysomnography, of whom 16/68 (23.5%) showed pathological results. No differences were observed in terms of OSAHS symptom presence or absence between the two groups. Demographics and baseline characteristics of the study cohort are reported in Table 1. Pre-pregnancy BMI and at test were significantly higher in women with positive versus negative pulse oximetry. The pulse oximetry parameters of the two groups are shown in Table 2. In group 1, lower baseline values of SaO_2%, average desaturation percentage, and nadir have been documented. Also, these patients presented higher ODI, SaO_2% < 90% time, and total number of desaturation events which were characterized by a shorter duration (Table 2; Figure 1). No differences in pregnancy complications, gestational age at delivery, cesarean section, and postpartum hemorrhage rates have been documented. Similar incidences of neonatal acidosis, NICU admission, and neonatal complications were observed in the two groups. The incidence of respiratory distress syndrome was higher in group 1 ($P = 0.082$). Newborns of women with positive pulse oximetry showed a significantly higher rate of congenital anomalies than the others ($P = 0.017$) (Table 3).

Similar results regarding BMI both pre-pregnancy and at the time of testing, length of second labor stage, and presence of congenital abnormalities can be documented when comparing pregnant women who tested positive on pulse oximetry and polysomnography with those who tested negative on pulse oximetry (Table 4). Also, lower Epworth sleepiness scale values and respiratory distress syndrome (RDS) incidence have been documented.

TABLE 1 Demographic and clinical characteristics of women with positive (group 1) or negative (group 2) pulse oximetry.

Variable	Positive pulse oximetry (group 1; $n = 44$)	Negative pulse oximetry (group 2; $n = 68$)	*P*-value
Maternal age at the test (year)	34.8 ± 5.1	33.2 ± 5.8	0.124
Caucasian race	31 (70.4)	46 (67.6)	0.836
Nulliparous	13 (29.5)	34 (50.0)	0.107
Pre-pregnancy BMI	37 ± 6.2	34 ± 4.4	**0.007***
BMI at test	37.5 ± 5.9	34.9 ± 4.5	**0.009***
BMI at delivery	38.3 ± 5.5	37.1 ± 4.8	0.249
GA at test (week)	16.4 ± 4.1	16.4 ± 4.4	0.983
Smoking habit	4 (9.1)	5 (7.4)	0.457
IVF	0	4 (5.9)	0.443
Asthma	1 (2.3)	3 (4.4)	1.000
Epworth sleepiness scale	5.6 ± 3.7	4.8 ± 3.4	0.582
SWIFT score	4.6 ± 5	4.6 ± 4.1	0.513
Berlin test positive for OSAHS	13 (29.5)	21 (30.9)	1.000
Snoring	30 (68.2)	39 (57.3)	0.149

Note: Data are given as mean ± SD or *n* (%). Statistically significant *P*–values in bold. *$P < 0.01$.

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters); GA, gestational age; IVF, in vitro fertilization; OSAHS, obstructive sleep apnea-hypopnea syndrome; SWIFT, sleepiness-wakefulness inability and fatigue test.

TABLE 2 Pulse oximetry parameters of the two groups.

Variable	Positive pulse oximetry (group 1, $n=44$)	Negative pulse oximetry (group 2, $n=68$)	*P*-value
GA at pulse oximetry (wk)	16.4 ± 4.1	16.4 ± 4.4	0.983
Duration of pulse oximetry (min)	434.8 ± 74.6	597.1 ± 1347.3	0.427
Basal oxygen saturation (%)	94.2 ± 1.3	95.0 ± 1.2	**0.001***
Total desaturation events (*n*)	82.6 ± 41.0	26.0 ± 16.7	**<0.001****
Average duration of the event (s)	43.6 ± 10.9	54.6 ± 17.2	**<0.001****
ODI	11.1 ± 5.9	3.3 ± 1.5	**<0.001****
Average desaturation (%)	92.1 ± 1.4	93.1 ± 1.2	**<0.001****
$SatO_2$ < 90% time (min)	5.9 ± 10.0	1.8 ± 10.5	**0.043***
Nadir_ SpO_2	81.8 ± 12.5	88.0 ± 5.1	**0.002***
Average heart rate (beats/min)	75 ± 7	74 ± 8	0.138

Note: Data are given as mean ± SD. Statistically significant *P*–values in bold. *$P < 0.05$; **$P < 0.001$.
Abbreviations: GA, gestational age; ODI, oxygen desaturation index.

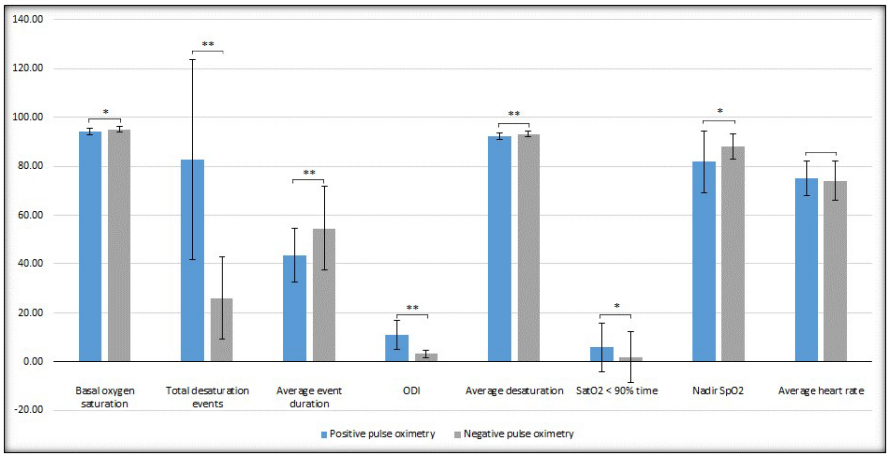

FIGURE 1 Descriptive comparison of the pulse oximetry parameters from the two groups. ODI, oxygen desaturation index. *$P < 0.05$; **$P < 0.001$.

Stepwise multivariate regression analysis showed that basal oxygen saturation was independently associated with FGR after correction for maternal BMI, age, gravidity, ethnicity, and hypertensive pregnancy disorders, while it was not independently associated with congenital abnormalities (Table 5). No correlations were observed for the total number of desaturation events or ODI with FGR or congenital abnormalities. In all multivariate analyses, BMI at the test significantly correlates with congenital abnormalities onset (Tables 6 and 7).

4 | DISCUSSION

Our study assessed the correlation between oxygen pulse oximetry in the first trimester of pregnancy and adverse perinatal outcomes in a cohort of obese women. Interestingly, we found a higher rate of congenital abnormalities in obese patients with altered nocturnal pulse oximetry. Moreover, our findings documented the role of maternal basal oxygen saturation in predicting the occurrence of FGR. It is well known that the incidence of OSAHS in pregnancy varies according to maternal BMI, being 8.5% in normal-weight pregnant women and 62% in obese subjects,[20] thus suggesting a close link between the two conditions, probably due to an inflammatory pathway. Furthermore, it has been postulated that fat accumulation in the body's upper portion, especially around the neck, may play a crucial role in promoting OSAHS.[21] Evidence from the literature documented associations between OSAHS and a wide range of pregnancy disorders, including hypertensive disorders, cesarean delivery, NICU admissions, pre-eclampsia, gestational diabetes, glomerular filtration rate, congenital anomalies, and resuscitation at birth. Therefore, OSAHS during pregnancy, regardless of whether it is a pre-existing condition or of new onset, can impair the pregnancy outcome. However, the underlying mechanisms are still not described in detail, and further molecular and pathophysiological studies are required. In addition, it would be valuable to consider this study, along with others documenting comparable results, as a way to develop innovative OSAHS screening approaches targeting obese women to reduce the risk of adverse pregnancy outcomes

TABLE 3 Pregnancy outcome of women with positive or negative pulse oximetry.

Variable	Positive pulse oximetry (group 1, $n=44$)	Negative pulse oximetry (group 2, $n=68$)	*P*-value
Length of first stage of labor (min)	68.2 ± 77.6	140.0 ± 142.7	**0.001***
Length of second stage of labor (min)	16.6 ± 21.4	36.60 ± 44.3	**0.008***
HDP	4 (9.1)	7 (10.3)	1.000
Gestational diabetes	22 (50.0)	30 (44.1)	0.556
Intrahepatic cholestasis of pregnancy	0	2 (2.9)	0.519
PPROM or cervical incontinence	2 (4.5)	1 (1.5)	0.560
FGR	1 (2.3)	2 (2.9)	1.000
GA at delivery (week)	38.0 ± 2.6	38.2 ± 1.5	0.784
Induction of labor	24 (54.5)	33(48.5)	0.559
Cesarean section	18 (40.9)	24 (35.3)	0.713
Postpartum hemorrhage	7 (15.9)	11 (16.2)	1.000
Birth weight (g)	3062.2 ± 695.0	3187.7 ± 556.0	0.298
Birth weight < 10th percentile	2 (4.5)	6 (8.8)	0.136
Umbilical artery pH	7.20 ± 0.08	7.24 ± 0.07	0,862
Umbilical artery BE	−3.5 ± 3.1	−3.3 ± 3.6	0.883
5-min Apgar score	9.5 ± 0.6	9.5 ± 0.6	0.984
NICU admission	5 (11.4)	4 (5.9)	0.480
Congenital abnormalities	6 (13.6)	1 (1.5)	**0.017***
RDS	5 (11.4)	2 (3.0)	0.082
Neonatal hypoglycemia	9 (20.4)	9 (13.2)	0.432
Neonatal infection	4 (9.1)	2 (3.0)	0.218
Neonatal jaundice	7 (15.9)	4 (5.9)	0.114

Note: Data are given as mean ± SD or *n* (%). Statistically significant *P*–values in bold. *$P < 0.05$.

Abbreviations: BE base excess; FGR, fetal growth restriction; GA, gestational age; HDP, hypertensive disorders of pregnancy; NICU, neonatal intensive care unit; PPROM, preterm premature rupture of membranes; RDS, respiratory distress syndrome.

through dedicated treatment and follow-up protocols. The association between OSAHS in pregnancy and placental-related complications have already been documented.[22,23] It has been demonstrated that OSAHS is linked to oxidative stress, systemic inflammation, and endothelial dysfunction due to chronic hypoxemia occurring during apnea episodes. Placental syndromes share similar findings, making OSAHS play a key role, along with the vascular and metabolic impairment observed in obesity, in determining the adverse outcomes described in the present study, which are consistent with those reported in the literature.

The association between high BMI levels and congenital abnormalities, likely due to fat-related metabolic abnormalities interfering with embryonic development, is another finding reported in the literature. In this picture, sleep disorders could be an additional driver besides being worsened by excessive weight.

This study provides useful hints regarding the impact of desaturation on pregnancy outcomes and OSAHS diagnosis applicable within a multidisciplinary context to develop management strategies tailored to individual obese pregnant women. These insights could be crucial for implementing preventive and therapeutic strategies, including sleep disorder screening tests, dietary and lifestyle adjustments, and the adoption of nocturnal ventilation systems such as continuous positive airways pressure. Also, it is worth clarifying that pulse oximetry should not be seen as a diagnostic substitute for polysomnography but as a first-line screening tool to identify pregnant women at higher risk of OSAHS development. Although we consider that this study has been conducted by employing reproducible criteria in terms of both patient enrollment and procedure execution, applicable at other centers, we acknowledge some limitations. The main ones are the inability to attribute causation due to the observational nature of the study and the employed screening questionnaires, which are validated in the non-pregnant population, and their reported sensitivities and specificities of 36%–39% and 68%–77%, respectively.[16–19] Also, a sample size estimation for assessing congenital abnormalities has not been performed due to the consecutive patients' enrollment within a pre-determined temporal range.

In conclusion, screening questionnaires for sleep disorders are an easy-to-use and low-cost tool to identify women requiring pulse oximetry evaluation. Focusing on the obese pregnant population, those with altered nocturnal pulse oximetry in the first trimester of gestation are at higher risk of developing congenital abnormalities. Basal oxygen saturation seems to predict the occurrence of FGR independently of several confounders. Large prospective and multi-center studies are needed to confirm our findings, which may impact the obstetric management of pregnant women.

TABLE 4 (a) Demographic and clinical characteristics of women with positive polysomnography and negative pulse oximetry. (b) Pregnancy outcome of women with positive polysomnography and negative pulse oximetry.

Variable	Positive polysomnography ($n=16$)	Negative pulse oximetry (group 2, $n=68$)	*P*-value
(a)			
Maternal age at the test (year)	35.6 ± 4.5	33.2 ± 5.8	0.117
Caucasian race	13 (81.3)	46 (67.6)	0.371
Nulliparous	3 (18.8)	34 (50.0)	**0.023**
Pre-pregnancy BMI	38.4 ± 7.0	34 ± 4.4	**0.030***
BMI at test	39.0 ± 6.7	34.9 ± 4.5	**0.031***
BMI at delivery	39.5 ± 5.7	37.1 ± 4.8	0.150
GA at test (week)	21.2 ± 4.4	16.4 ± 4.4	
Smoking habit	3 (18.8)	5 (7.4)	0.173
IVF	0	4 (5.9)	0.804
Asthma	0	3 (4.4)	1.000
Epworth sleepiness scale	7.9 ± 4.5	4.8 ± 3.4	**0.026***
SWIFT score	5.4 ± 6.0	4.6 ± 4.1	0.643
Berlin test positive for OSAHS	5 (31.2)	21 (30.9)	1.000
Snoring	12 (75.0)	39 (57.3)	0.147
(b)			
Length of first stage of labor (min)	71.3 ± 98.3	140.0 ± 142.7	0.072
Length of second stage of labor (min)	10.2 ± 16.8	36.60 ± 44.3	**0.001***
HDP	2 (12.5)	7 (10.3)	0.679
Gestational diabetes	8 (50.0)	30 (44.1)	0.782
Intrahepatic cholestasis of pregnancy	0	2 (2.9)	1.000
PPROM or cervical incontinence	0	1 (1.5)	1.000
FGR	0	2 (2.9)	1.000
GA at delivery (week)	38.5 ± 2.2	38.2 ± 1.5	0.559
Induction of labor	8 (50.0)	33(48.5)	0.782
Cesarean section	6 (37.5)	24 (35.3)	0.868
Postpartum hemorrhage	3 (18.8)	11 (16.2)	0.711
Birth weight (g)	3247.5 ± 643.2	3187.7 ± 556.0	0.716
Birth weight < 10th percentile	0	6 (8.8)	0.495
Umbilical artery pH	7.22 ± 0.09	7.24 ± 0.07	0,205
Umbilical artery BE	−3.2 ± 2.8	−3.3 ± 3.6	0.873
5-min Apgar score	9.6 ± 0.6	9.5 ± 0.6	0.740
NICU admission	2 (12.5)	4 (5.9)	0.331
Congenital abnormalities	3 (18.8)	1 (1.5)	**0.022***
RDS	3 (18.8)	2 (3.0)	**0.048***
Neonatal hypoglycemia	5 (31.3)	9 (13.2)	0.132
Neonatal infection	2 (12.5)	2 (3.0)	0.169
Neonatal jaundice	3 (18.8)	4 (5.9)	0.130

Note: Data are given as mean ± SD or *n* (%). Statistically significant *P*–values in bold. *$P < 0.05$.

Abbreviations: BE base excess; BMI, Body Mass Index; FGR, fetal growth restriction; GA, gestational age; HDP, hypertensive disorders of pregnancy; IVF, in vitro fertilization; NICU, neonatal intensive care unit; RDS, respiratory distress syndrome; OSAHS, obstructive sleep apnea-hypopnea syndrome; PPROM, preterm premature rupture of membranes; SWIFT, sleepiness-wakefulness inability and fatigue test.

TABLE 5 (a) Multivariate regression analysis to assess the association between maternal BMI, basal oxygen saturation, maternal age, ethnicity, gravidity, and hypertensive disorders of pregnancy as independent variables and FGR as dependent variable. (b) Multivariate regression analysis to assess the association between maternal BMI and basal oxygen saturation as independent variables and congenital abnormalities as dependent variable.

Variable	OR	95% CI	*P*-value
(a)			
BMI at test	0.92	0.56–1.50	0.755
Basal oxygen saturation	0.13	0.02–0.78	**0.025***
Maternal Age	2.36	0.84–6.64	0.103
Ethnicity	0.17	0.00–42.87	0.539
Gravidity	0.42	0.09–2.02	0.286
Hypertensive disorders of pregnancy	7.74	0.04–1347.31	0.437
(b)			
BMI at test	1.21	1.06–1.37	**0.003***
Basal oxygen saturation	0.82	0.43–1.56	0.552

Abbreviations: CI, confidence interval; OR, odds ratio. Statistically significant *P*–values in bold. *$P < 0.05$.

TABLE 6 (a) Multivariate regression analysis to assess the association between maternal body mass index (BMI, calculated as weight in kilograms divided by the square of height in meters), desaturation events, maternal age, ethnicity, gravidity, and hypertensive disorders of pregnancy as independent variables, and fetal growth restriction as a dependent variable. (b) Multivariate regression analysis to assess the association between maternal BMI and desaturation events as independent variables, and congenital abnormalities as dependent variables.

Variable	OR	95% CI	*P*-value
(a)			
BMI at test	0.97	0.68–1.40	0.889
Total desaturation events	1.00	0.97–1.03	0.953
Maternal age	1.29	0.95–1.76	0.101
Ethnicity	0.49	0.12–19.26	0.703
Gravidity	0.49	0.12–2.02	0.325
Hypertensive disorders of pregnancy	6.31	0.30–132.18	0.235
(b)			
BMI at test	1.218	1.07–1.38	**0.002***
Basal oxygen saturation	1.000	0.98–1.02	0.977

Abbreviations: CI, confidence interval; OR, odds ratio. Statistically significant *P*–values in bold. *$P < 0.005$

TABLE 7 (a) Multivariate regression analysis to assess the association between maternal body mass index (BMI, calculated as weight in kilograms divided by the square of height in meters), oxygen desaturation index (ODI), maternal age, ethnicity, gravidity, and hypertensive disorders of pregnancy as independent variables and fetal growth restriction as dependent variable. (b) Multivariate regression analysis to assess the association between maternal BMI and ODI as independent variables and congenital abnormalities as dependent variable.

Variable	OR	95% CI	*P*-value
(a)			
BMI at test	0.93	0.62–1.39	0.728
ODI	1.02	0.80–1.29	0.871
Maternal age	1.26	0.94–1.70	0.116
Ethnicity	0.39	0.11–14.57	0.615
Gravidity	0.50	0.12–2.14	0.358
Hypertensive disorders of pregnancy	3.99	0.23–68.38	0.339
(b)			
BMI at test	1.21	1.07–1.38	**0.003***
ODI	1.02	0.90–1.15	0.754

Abbreviations: CI, confidence interval; OR, odds ratio. Statistically significant *P*–values in bold. *$P < 0.005$.

AUTHOR CONTRIBUTIONS

Study design: Rossana Orabona, Luciano Corda, Cristina Zanardini. Data collection: Luciano Corda, Matteo Bernardi, Claudia Maggi, Giorgia Mazzoni, Leonardo Pedroni, Silvia Uccelli. Interpretation of the results: Rossana Orabona, Luciano Corda, Jordan Giordani, Sonia Zatti, Cristina Zanardini. First draft: Rossana Orabona, Luciano Corda, Jordan Giordani, Cristina Zanardini. Revision: Rossana Orabona, Luciano Corda, Sonia Zatti, Enrico Sartori, Cristina Zanardini.

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CONFLICT OF INTEREST STATEMENT

RO: reports no conflict of interest for this work. LC: reports no conflict of interest for this work. JG: reports no conflict of interest for this work. MB: reports no conflict of interest for this work. CM: reports no conflict of interest for this work. GM: reports no conflict of interest for this work. LP: reports no conflict of interest for this work. SU: reports no conflict of interest for this work. SZ: reports no conflict of interest for this work. ES: reports no conflict of interest for this work. CZ: reports no conflict of interest for this work.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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