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Sleep and sleep disorders during pregnancy and postpartum: The Life-ON study

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ABSTRACT

Objective: to prospectively assess sleep and sleep disorders during pregnancy and postpartum in a large cohort of women.

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Sleep related breathing disorder
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Methods: multicenter prospective Life-ON study, recruiting consecutive pregnant women at a gestational age between 10 and 15 weeks, from the local gynecological departments. The study included home polysomnography performed between the 23rd and 25th week of pregnancy and sleep-related questionnaires at 9 points in time during pregnancy and 6 months postpartum.
Results: 439 pregnant women (mean age 33.7 ± 4.2 yrs) were enrolled. Poor quality of sleep was reported by 34% of women in the first trimester of pregnancy, by 46% of women in the third trimester, and by as many as 71% of women in the first month after delivery. A similar trend was seen for insomnia. Excessive daytime sleepiness peaked in the first trimester (30% of women), and decreased in the third trimester, to 22% of women. Prevalence of restless legs syndrome was 25%, with a peak in the third trimester of pregnancy. Polysomnographic data, available for 353 women, revealed that 24% of women slept less than 6 h, and 30.6% of women had a sleep efficiency below 80%. Sleep-disordered breathing (RDI≥5) had a prevalence of 4.2% and correlated positively with BMI.
Conclusions: The Life-ON study provides the largest polysomnographic dataset coupled with longitudinal subjective assessments of sleep quality in pregnant women to date. Sleep disorders are highly frequent and distributed differently during pregnancy and postpartum. Routine assessment of sleep disturbances in the perinatal period is necessary to improve early detection and clinical management.

1. Introduction

Pregnancy is a physiological condition characterized by deep anatomic, metabolic, hormonal and psychological changes. Any alteration in the delicate balance of these factors may compromise a healthy outcome and induce pregnancy-related complications such as gestational diabetes, hypertension, pre-eclampsia and perinatal depression (PND).

Sleep and pregnancy are reciprocally linked, with pregnancy inducing changes in sleep and related disorders, and sleep disorders affecting pregnancy and its outcome. Sleep disturbances are known to be very common during pregnancy [1] and the postpartum period [2]. More than 40% of pregnant women report poor sleep quality and reduction of total sleep time [3]. Daytime sleepiness seems to be particularly frequent in the first trimester of pregnancy, while insomnia appears to be more common in the third trimester, together with restless legs syndrome (RLS) and sleep apnea [4]. Insomnia and RLS are known to increase the risk of perinatal depression (PND) [5]. Obstructive sleep apnea (OSA) is a risk factor for gestational hypertension [2] and affects fetal growth and APGAR score at birth [6]. While cross-sectional studies of subjectively reported sleep-related symptoms have been described in the literature, available results depend on the time of gestation and on the objectivity of assessment tools used [3]. Although polysomnographic (PSG) studies provide accurate information about sleep, their use is limited by feasibility and costs involved. As a consequence, prospective sleep studies are few, and generally limited in size and scope [7]. Only prospective, large-scale cohort studies combining subjective and objective information from pregnant and puerperal women, can provide solid knowledge on sleep disorders during pregnancy.

The main aim of the analysis presented in the current paper was to assess sleep and the major sleep disorders during pregnancy and a 6-months postpartum period, from a large polysomnographic prospective cohort study.

2. Methods

2.1. Data collection

The presented results derive from the prospective multicenter Life-ON Study (Perinatal Depression: Chronobiology, Sleep related Risk Factors and Light Therapy, 320030_160250/1); details on the complete study protocol have previously been published [8].

The Life-ON study aimed to identify sleep-related risk factors for perinatal depression. A large, naturalistic, consecutive cohort of pregnant women was recruited between May 2016 and November 2019 by the Department of Gynecology of four hospitals, in Bologna, Milan and Turin (Italy) and in Lugano (Switzerland), and followed up to one year after delivery. In the current paper are presented follow-up data up to 6 months after delivery. Sleep centers are located in urban Italian speaking areas of northern Italy and southern Switzerland (Ticino, Italian speaking Canton). All women gave written informed consent to participate in the study and the study was approved by local ethical committees.

The inclusion criteria for the study were: age between 18 and 55 years, lack of major medical conditions, and gestational age between 10 and 15 weeks at the time of inclusion. Exclusion criteria were: any psychiatric diagnosis, recent or current use of psychotropic drugs (within the last 6 months), and intrauterine fetal death.

Participating women underwent eleven scheduled visits, three of which were face-to-face (one per trimester of pregnancy) and eight were either face-to-face visits or telephone conversations during twelve months postpartum (Table 1). Participants were examined by a multidisciplinary team of gynecologists, psychologists, psychiatrists, and neurologist experts in sleep medicine.

2.2. Sleep questionnaires and reporting scales

Sleep quality was assessed by the Pittsburgh Sleep Quality Index (PSQI): a self-administered 18-item questionnaire with scores ranging between 0 and 21, where a score higher than or equal to 5 identifies poor-quality sleep [9].

The presence and severity of insomnia were assessed by the Insomnia Severity Index (ISI): a self-administered 7-item questionnaire with scores ranging between 0 and 28, where a score between 8 and 14 identifies subthreshold insomnia, a score between 15 and 21 moderate insomnia, and scores higher than 21 severe insomnia [10].

Daytime sleepiness was assessed by the Epworth Sleepiness Scale (ESS): a self-administered 8-item questionnaire with scores ranging between 0 and 24, where scores higher than 10 identify pathological sleepiness [11].

The presence of restless legs syndrome (RLS) was assessed in a face-to-face interview. Women fulfilling the five standard diagnostic criteria for RLS [12] were classified as affected and were further assessed to quantify the severity of their symptoms using the International RLS Study Group Rating Scale (IRLS) [13].

2.3. Polysomnography

With each participant, a full night home unattended polysomnography (PSG) was conducted (Embla MPR/ST/Proxy, Remlogic), between the 23rd and 25th gestational week. The following parameters were monitored: electroencephalogram, electro-oculogram, electromyogram of submentalis and bilateral tibialis anterior muscles, electrocardiogram, airflow, thoracic and abdominal efforts, oxygen saturation, body position and microphone. Sleep and related events (arousals, breathing events, periodic limb movements during sleep)

were first scored by a sleep specialist per center, and then centrally and blindly reviewed by a single sleep specialist (SR, neurologist), following standard guidelines [14]. In particular, to score hypopneas we used the recommended criteria (≥3% oxygen desaturation from pre-event baseline). Sleep disordered breathing was defined by a respiratory disturbance index (RDI) ≥ 5. Periodic limb movements (PLM) were defined as leg movements longer than 0.5 s and shorter than 10 s, when a series of at least 4 movements, with an inter-movement interval ranging between 10 and 90 s, where met. The PLMS index indicated the number of PLMS per hour of sleep. Awakenings are defined as wake EEG activity longer then 15 s.

2.4. Statistical analysis

In data processing, no imputation of missing values was performed. All women were a priori included in the analyses and only excluded from specific computations whenever one of the variables under focus was missing. The demographic characteristics of the group of women who completed the study were compared against those of the group of women who had dropped out, and differences were tested for significance using the *t*-test for age and BMI, and the Pearson's chi-square test for educational levels and smoking habits. The *t*-test was used also for testing differences in the ISI, PSQI and ESS indexes between parity groups and between age groups. Spearman's rank-correlation coefficient (r_s) was used for testing significance of pairwise correlations between variables. All statements of significance are based on a significance level of 0.05.

3. Results

Four hundred and thirty-nine pregnant women (age: mean = 33.7 yrs, std = 4.2) were recruited. The present paper provides data collected up to 6 months after pregnancy, when 299 (68.1%) women were still regularly followed, while 140 (31.9%) had dropped out. The number of data collected for each variable are given in Tables 1 and 2. No significant differences in demographic characteristics (Table 2) were found between the women who completed the study and the women who dropped out (with $p = 0.76$ for age, $p = 0.34$ for BMI at visit 1, $p = 0.10$ for educational level, and $p = 0.48$ for smoking).

3.1. Sleepiness

Excessive daytime sleepiness (EDS) was reported by 46.9% women; these women had an ESS score higher than 10 in at least one of the 9 visits. During pregnancy, EDS was reported at least once by 40.7% of women. The mean of the ESS scores was highest in the first trimester of pregnancy (Fig. 1, *top left*), with 30.3% of women reporting a score higher than 10. Except for a transient plateau around delivery, sleepiness decreased over time, to 13.0% at visit 8 and 9.8% at visit 9.

Despite weak, ESS correlated with insomnia (ISI) and with poor sleep quality (PSQI) with correlation coefficients for the PSQI ranging from 0.1 to 0.27 (p-value<0.005) and from 0.2 to 0.39 (p-value>0.005) for the ISI score. Moreover, the Spearman rank correlation coefficient of the ESS and ISI scores averaged over all six visits was $r_s = 0.362$ ($p < 0.005$) and the correlation coefficient of the average ESS and PSQI scores was $r_s = 0.241$ ($p < 0.005$). Only women without missing values for both ISI and ESS, and, respectively, ESS and PSQI were included in these analyses. No significant correlation was found of daytime sleepiness at visit 2 with respiratory disturbance (RDI) ($r_s = 0.038$, $p = 0.492$), nor with PLMS ($r_s = 0.0015$, $p = 0.978$).

Daytime sleepiness is present similarly in multiparous and in primiparous women (Fig. 2, *top left*). A negative correlation was found between ESS and age, which was only significant in the period immediately following delivery, i.e. visit 5; at this visit, women older than 37 years of age showed significantly lower ESS scores on average than younger women ($p = 0.0041$).

3.2. Quality of sleep and insomnia

Fig. 1 (*bottom left*) shows the trend of sleep quality (PSQI) and that of insomnia (ISI) (*top right*) throughout pregnancy and the puerperium. Both mean scores peaked around the time of delivery.

Sleep quality was judged to be poor by 33.7% of women in the first trimester of pregnancy, with this percentage increasing to 34.7% and 46.2% in the second and third trimesters respectively. Three weeks after delivery (visit 5), the mean of the observed PSQI scores peaked, with poor sleep quality for 71.4% of the women, which remained poor for almost half of the sample up to visit 9. Eighty-two percent of women had a PSQI score of 5 or above in at least one of the visits. Sleep quality was worse in multiparous women than in primiparous (Fig. 2, *bottom left*) and showed a positive correlation with age which was only significant at visit 2.

The mean ISI score followed similar trends, with insomnia peaking in the third trimester of pregnancy (31.5%), and immediately after delivery (34.4%) (Fig. 1, *top right*). The percentage of women experiencing insomnia dropped to 15.9% 7 weeks after delivery. 247 women (56.3%) indicated insomnia at least once in visits 1 to 9. Insomnia (higher score of ISI) was found to correlate with low sleep quality (higher score of PSQI), with correlation coefficients between the ISI and PSQI scores ranging from $r_s = 0.650$ at visit 5 to $r_s = 0.752$ at visit 3, with *p*-values<0.005.

The ISI score neither correlated with the RDI score (correlation coefficient $r_s = 0.0639$, with $p = 0.25$) nor with PLMS ($r_s = 0.0886$, $p = 0.11$). Insomnia was significantly more represented among multiparous women than among primiparous women (Fig. 2, *top right*), with $p = 0.0325$ at visit 1 and $p = 0.019$ at visit 2. Insomnia and age showed a positive correlation, yet without reaching statistical significance.

Table 1
Assessment tools and time schedule of their administration of the 3 visits during pregnancy and the 6 visits during the post-partum period.

	PREGNANCY			POSTPARTUM					
	V1	**V2**	**V3**	**V4**	**V5 (T)**	**V6**	**V7 (T)**	**V8**	**V9**
	(10–15 W)	(23–25 W)	(34–36 W)	(1 W) (5–12 d)	(3 W) (19–26 d)	(5 W) (33–40 d)	(7 W) (47–54 d)	(3 M) (90–105 d)	(6 M) (180–195 d)
PSQI	•	•	•		•			•	•
ISI	•	•	•		•		•	•	•
ESS	•	•	•		•			•	•
RLS criteria + Severity Scale	•	•	•	•		•		•	•
MEQ	•								
PSG		•							

Footnote: All visits were performed face to face, except V5 and V7 (T), that were performed either in person or over the telephone depending on patient availability.

Table 2
The demographic and behavioral characteristics collected from the study group, with their summary statistics.

Categorical Variables	Categories	Number of observations	Relative percentage (%)
Marital status	**Total**	**439**	
	Married	257	58.5
	Cohabitation	178	40.5
	Single	3	0.7
	Divorced	1	0.2
Work	**Total**	**414**	
	Permanent position	280	67.6
	Fixed-term position	72	17.4
	Unemployed	62	15.0
Education	**Total**	**437**	
	Higher education	284	65.0
	Secondary education	129	29.5
	Primary education or less	24	5.5
Smoke	**Total**	**431**	
	No	403	93.5
	Yes	28	6.5
Alcohol	**Total**	**437**	
	No	420	96.1
	Yes	17	3.9
First Pregnancy	**Total**	**436**	
	No	247	56.7
	Yes	189	43.3
Twin pregnancy	**Total**	**439**	
	No	437	99.5
	Yes	2	0.5

Continuous variables	Number of observations	Mean	Standard deviation	Median	[1st – 3rd quantile]
Age	439	33.720	4.210	34.000	[31.000–37.000]
Number of cigarettes per day (limited to smokers)	28	5.462	3.772	5.000	[2.8750–7.6250]

BMI	Number of observations	Mean	Standard deviation	Median	[1st – 3rd quantile]	Percentage with BMI >25
Visit 1	414	22.936	3.449	22.227	[20.569–24.609]	23.4
Visit 2	353	24.713	3.447	24.129	[22.206–26.678]	38.0
Visit 3	311	26.4	3.534	25.654	[23.934–28.715]	58.8
Visit 4	135	24.589	3.544	24.219	[22.218–26.817]	38.5
Visit 6	248	23.726	3.394	23.078	[21.229–25.966]	30.2
Visit 8	193	23.711	3.482	22.893	[21.107–25.864]	31.1
Visit 9	149	23.269	3.447	22.578	[20.703–25.469]	28.2

3.3. Restless legs syndrome

Fig. 1 (*bottom right*) shows the trend of RLS occurrence, which peaked during the second and third trimesters of pregnancy. Around delivery, RLS prevalence dropped and reduced to 5.7% by visit 9. RLS was experienced in at least one of the visits 1 to 3 during pregnancy by 25% of women. The percentage of women experiencing RLS during their current pregnancy for the first time at visit 1, was 12.1%, while 13.7% reported to have already experienced RLS symptoms before the current pregnancy. Among the women presenting with RLS at visit 1, 2.0% had mild RLS, 51.0% had moderate RLS, and 9.8% had severe or very severe RLS. These percentages were 3.8%, 50.9% and 18.9% during the 3rd trimester of pregnancy.

3.4. Polysomnographic data

Table 3 reports the summary statistics of the polysomnographic data obtained from 353 women who underwent home recordings. Sleep macrostructure was basically preserved (Fig. 3). The sleep stage percentages were similar across the four centers. 24.6% of women slept less than 6 h, 41.4% of women more than 7 h, and 9.9% slept more than 8 h. The mean sleep efficiency was 83.0% (std 10.6%), with 30.0% of women having an SE lower than 80%. The mean latency of sleep to N1 was 16.8 min (std 18.4), with 28.3% of women having a latency longer than 20 min. Sleep proved fragmented both in term of mean number of awakenings and mean number of arousals per hour, with mean time of wakefulness after sleep onset (WASO) longer than 1 h.

3.5. Sleep disordered breathing

Sleep disordered breathing (RDI≥5) was found in 15 (4.2%) women; 93.3% of them had mild SDB, 6.7% suffered from moderate SDB (15 ≤ RDI <30), and none had severe SDB (RDI ≥30). The mean AHI in the whole population was 1.4 (S.D. 1.9). Averaged over the whole population of pregnant women, the mean AHI in supine position was 2.2 (std 3.7), and the mean AHI in non-supine position was 0.9 (std 1.5). Women with an AHI ≥5 had a mean AHI of 8.61, a mean AHI supine of 11.9, and a mean AHI in REM of 28.3. The women with SDB had mostly obstructive hypopneas and respiratory-effort related arousals (RERA). The mean AHI in REM over all women was 5.2 (std 6.9), and the mean AHI in NREM was 0.5 (std 1.1). Averaged over all women, the mean time spent in supine position was 37.4% (std 22.3%); this percentage was 43.6% (std 24%) for women with AHI ≥5. The RDI was not available for position and sleep stage related statistics. The RDI score correlated positively with the BMI (correlation coefficient $r_s = 0.253$, with $p < 0.005$) (Fig. 4).

3.6. Periodic limb movements

Periodic limb movements during sleep (PLMS) were frequent in our study, with a mean PLMS index of 10.5 (std 17.3). 45% of women had a PLMS index higher than 5, 22.4% an index over 15, and 8.5% an index over 30. 31% percent of the women with a PLMS index equal or over 15 were also affected by RLS during pregnancy, while this percentage was 10% among the women with a PLMS index smaller than 15 ($p < 0.005$).

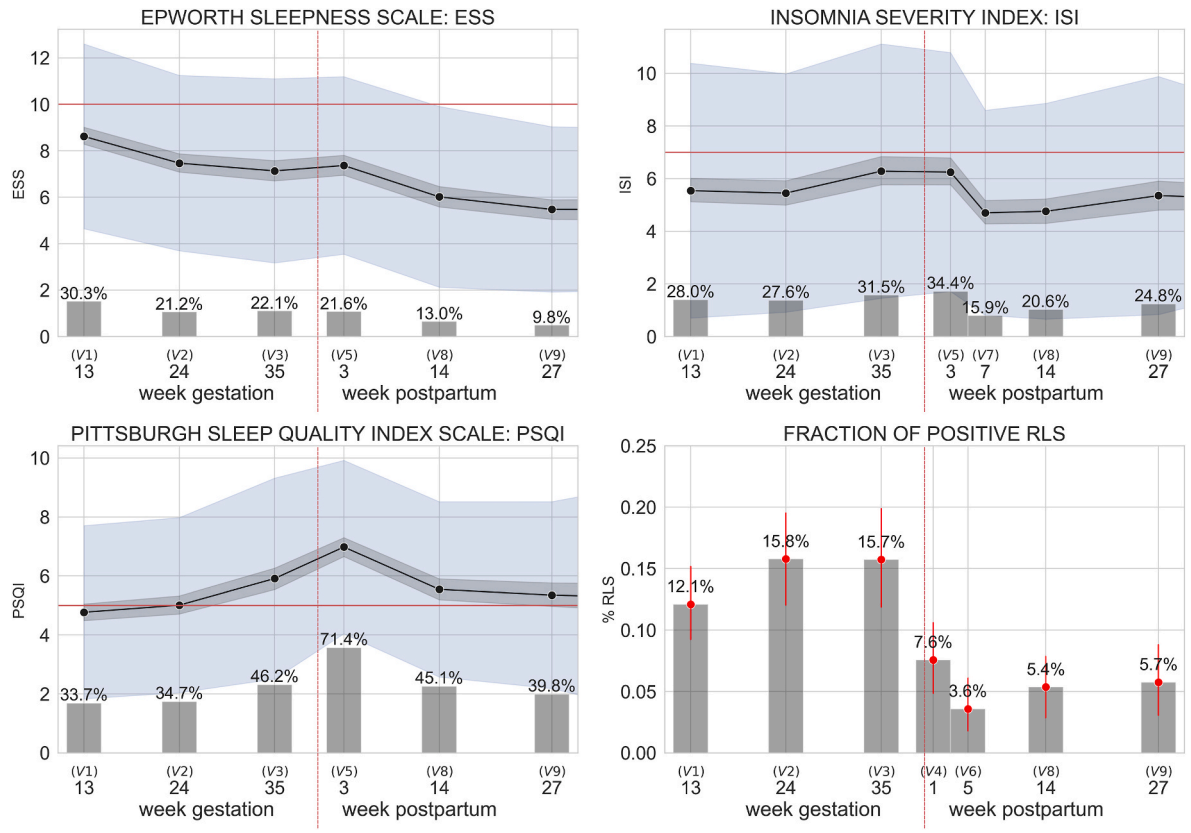

Fig. 1. Sleep scores over time, and the fraction of positive RLS (*bottom right*). The trends of the averaged ESS (*top left*), ISI (*top right*) and PSQI (*bottom left*) scores are shown, with standard deviations of the data indicated in light grey and bootstrap 95%-confidence intervals for the mean in dark grey. The horizontal red line marks the pathological threshold value used; the vertical red line indicates the time of delivery. The bars below the three figures with the ESS, ISI and PSQI scores indicate the percentage of women presenting with scores above the pathological threshold value.

4. Discussion

In the Life-ON Study, prospective data on sleep were collected from 439 pregnant women during pregnancy and 6-moths postpartum, together with the largest collection of polysomnographies in pregnant women to date.

A generally poor quality of sleep was found in our naturalistic cohort during pregnancy and the first six months postpartum, with a progressive increase of PSQI scores. A recent meta-analysis showed that 45.7% of pregnant women had a PSQI score of at least 5 (mean PSQI score 6.07) [3]. Longitudinal studies have shown mean PSQI scores to increase by 1.68 from the second to the third trimester, with gestational age being a significant moderator of heterogeneity. Our findings confirm these meta-analytic results and suggest age and parity status as risk factors for poor sleep quality. By performing a longitudinal assessment of PSQI across pregnancy and puerperium, Thomfohr et al. confirmed a progressive worsening of sleep quality [15]. However, the authors were able to identify 4 different trajectories of PSQI trend, with the one with highest values at the beginning of pregnancy and those with a progressive worsening of score, being more correlated positively with the develop of perinatal depression than the other groups of women.

A similar trend was observed in our study for insomnia, which was found in over 30% of women across the third trimester and immediate post-delivery period. From the literature, insomnia appears among the most prevalent sleep disorders during pregnancy, with rates ranging from 20% to 70% of women and increasing across pregnancy [16]. Unlike the previous literature, our findings suggest the poorest sleep quality and the highest peak of insomnia do not occur during pregnancy but rather immediately after delivery. Multipara women reported more often insomnia and low sleep quality in comparison with women at their first pregnancy. On the contrary, one might expect the opposite, with women with other children being more efficient than primiparous ones. Probably other factors, like age and familiar burden might explain this result.

More than 45% of the women in our study reported EDS during their pregnancy, with a peak in the first trimester, followed by a reduction over time, of both the mean reported score and the prevalence. A clear reduction of EDS was reached only at 6 months after delivery, when the mean score of ESS decreased lower than 6, and the percentage of women with score of EDS higher than 10 decreased lower than 10%. While daytime sleepiness was found to correlate positively with insomnia and sleep quality, no correlation with parity status, RDI or PLMS was found. This finding suggests that other factors than clearly identifiable sleep disorders govern daytime sleepiness in early pregnancy. The high level of EDS in the first period of pregnancy, when other sleep disorders, such as SBD, insomnia or RLS are low prevalent, reinforces the idea that early pregnancy related EDS might have a different origin in comparison with late pregnancy.

Older women presented lower EDS in the post-partum period, this may depend on their greater experience in managing the newborn, or on their lower need in night sleeping in comparison with younger women.

Facco et al. estimated the prevalence of EDS (defined as ESS >10) at 32% and 38% in the 13th and 30th week of pregnancy respectively and, hence, did not describe a reduction in prevalence across pregnancy [17]. In a large cross-sectional study, Mindell et al. also did not find a significant change in prevalence of EDS (as ESS ≥10) across pregnancy, with percentages of EDS ranging between 43% and 51% [18]. In a study of 100 women in late pregnancy, Sarberg et al. found a prevalence of EDS (also as ESS ≥10) of 42%, without any correlation of EDS with snoring or AHI [19]. No solid prospective findings on EDS in the first

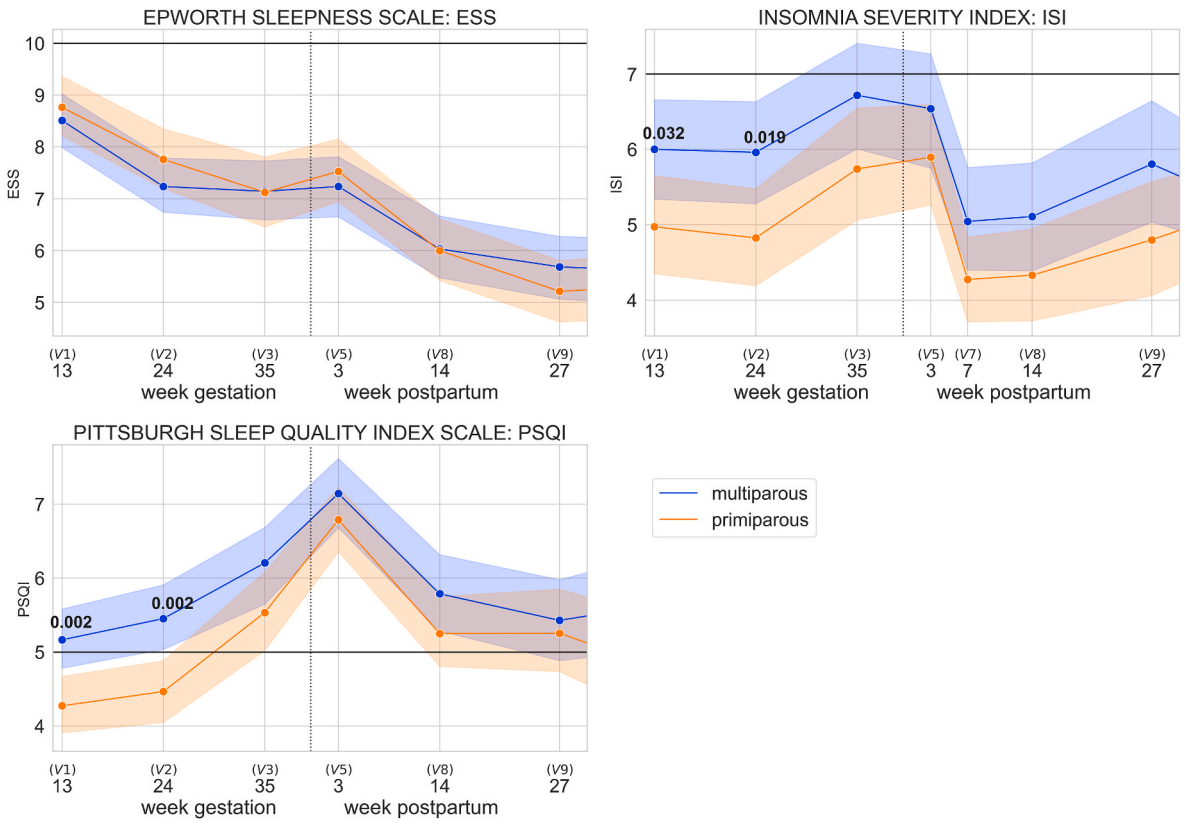

Fig. 2. The mean ESS, ISI and PSQI scores for primiparous and multiparous women respectively with bootstrap 95% confidence intervals represented by the shaded areas. The threshold values used are indicated by thick horizontal lines; the vertical lines indicate the time of delivery. The *p*-values of a *t*-test for difference between means of the two groups of women, which are significant at 0.05, are shown. No correction for multiple comparisons was performed.

Table 3
Summary statistics of the polysomnographic data obtained from 353 women between the 23rd and 25th week of pregnancy.

PSG parameters	Mean	Std. Dev.	Median	[1st – 3rd quantile]
TRT (min)	478.7	58.3	479.9	[444.1–521.8]
TST (min)	397.3	66.8	404.0	[361.5–441.8
SE (%)	83.0	10.6	85.5	[78.3–90.4]
N1 (%)	11.1	4.1	10.7	[8.5–13.2]
N2 (%)	46.3	6.6	46.3	[42.4–51.0]
N3 (%)	22.3	6.8	21.7	[17.7–25.8]
REM (%)	20.2	4.2	20.6	[17.8–22.7]
Latency to N1 (min)	16.8	18.4	10.5	[5.0–22.5]
Latency to N2 (min)	19.5	19.3	13.2	[7.5–25.5]
Latency to REM (min)	83.6	40.6	71.5	[60.5–96.0]
RDI	1.4	2.0	0.8	[0.3–1.8]
AHI	1.4	2.0	0.7	[0.3–1.8]
AHI (supine)	2.2	3.7	0.9	[0.0–2.8]
AHI (non-supine)	0.9	1.5	0.3	[0.0–1.0]
AHI (REM)	5.2	6.9	3.0	[1.0–7.0]
ODI (3%)	0.8	1.9	0.2	[0.0–0.8]
Mean SaO2 (%)	94.5	11.6	96.2	[95.1–97]
PLMSI	10.5	17.3	4.1	[1.0–13.1]
AI	12.2	4.3	11.5	[9.0–14.9]
N. Awakenings	24.0	8.9	23.0	[17.0–29.0]
WASO (min)	65.5	45.9	51.1	[32.5–86.4]

Footnote: TRT = total recording time; TST = total sleep time; AHI = apnea hypopnea index; RDI = respiratory disturbance index; ODI = oxygen desaturation index; PLMSI = periodic limb movements index; AI = arousal index; SE = sleep efficiency; WASO = wake after sleep onset.

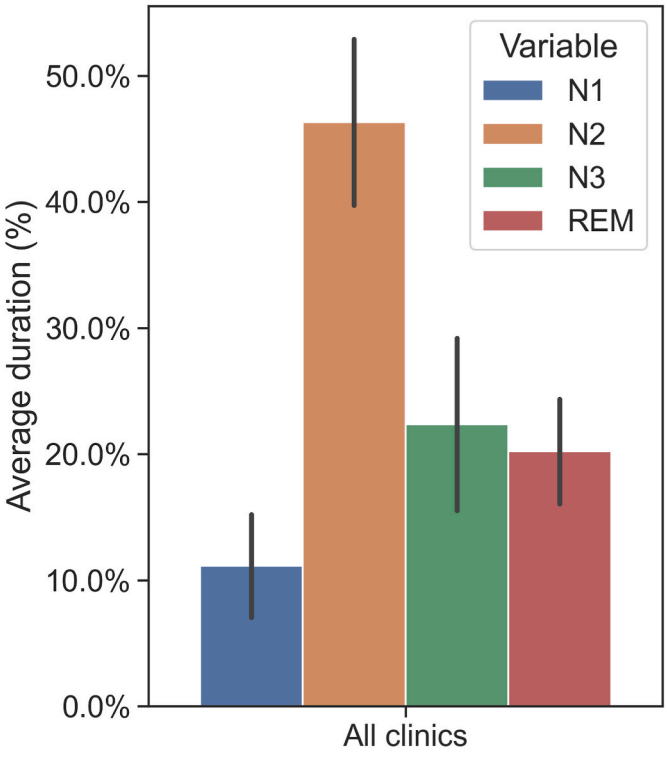

Fig. 3. Percentages of the four phases of sleep, averaged over all centers of recruitment.

year postpartum are available from the literature. These differences might be explained by the heterogeneity of population studied in term of age, BMI and socioeconomic status.

In our study, the overall prevalence of RLS during pregnancy was

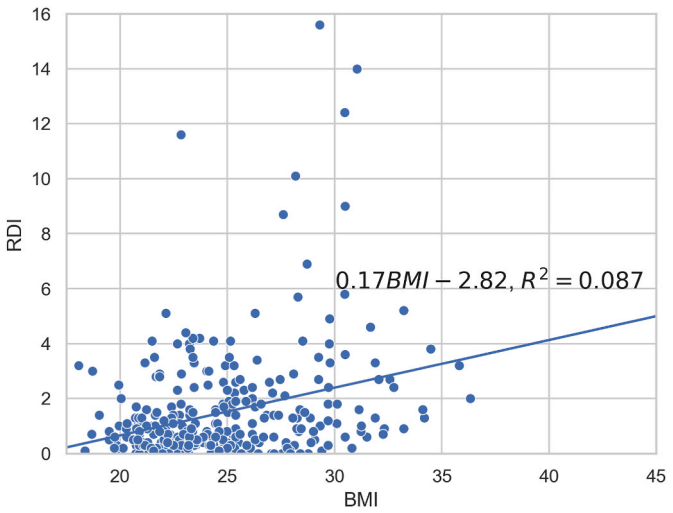

Fig. 4. A scatterplot of the RDI score of respiratory disturbance versus BMI, with the least-squares regression line.

found to be 25%, with peaks in the second and third trimesters. This finding is in agreement with two studies on the occurrence of RLS in comparable populations of pregnant women in Northern Italy. Esposito et al. [20], reported a 20.4% prevalence of RLS, and Manconi et al. found a prevalence of 26% in the same geographic area [21]. Half of our women had suffered from similar symptoms previously in their life, without being pregnant. This finding supports the hypothesis that a genetic predisposition plays an important role in pregnancy-related RLS [22]. In our study group, around 19% of the RLS-positive women graded their symptoms in late pregnancy as "severe" or "very severe". As confirmed by Hubner et al., the common view that RLS during pregnancy is usually mild may thus need some revision [23]. These results, combined with the associated high risk of future idiopathic RLS and with the described correlation between pregnancy-related RLS and PND [5], support active dissemination of knowledge and distribution of existing guidelines for RLS management during pregnancy to all gynecologists [24].

PLMS was a frequent finding in our study group, considering the young age and gender of the subjects involved: in the general population, PLMS is known to increase with age and is predominant in males. As expected, RLS correlated significantly with PLMS. The very few studies assessing PLMS during pregnancy did not report differences or just a mild increase of PLMS, when comparing pregnant to non-pregnant women [7]. Wilson et al. found a similar high prevalence of PLMS in pregnancy, however this study focused on SDB in hypertensive and obese women, with PSG data coming from different time points across pregnancy [25].

Sleep macrostructure was essentially preserved in our study group, with a tendency towards a fragmentation and a decreased SE and TST. Previous available PSG data from pregnant women are based on very few studies on smaller samples. The largest available study was reported by Izci-Balserak et al., who obtained recordings from 123 women in the first trimester of their pregnancy and from 97 women in the third trimester [26]. In comparison, our results showed better sleep quality, and a higher percentage of N3. Similarly, Wilson et al. found percentage of N3 slightly higher than us, together with a lower values of REM sleep [27]. These differences may be due to a variety of factors, such as the mean age of the women (higher in our study group), a different time of PSG assessment, and the location where the PSG was performed (recordings at home in our study versus recordings in a sleep lab in the Izci-Balserak et al. study). There are no consistent studies known in which a PSG was performed in the same period of pregnancy as ours [7].

Polysomnographic data on sleep-related breathing abnormalities in (healthy) pregnant women are scarce and divergent. If non-polysomnographic studies are considered, SDB is frequently reported during pregnancy, with a prevalence ranging between 12% and 32%, depending on its definition [28,29]. Izci-Balserak et al. found a prevalence of OSA (AHI >5) of 14% and 26% in the first and third trimesters, which was substantially lower (4.2%) in our larger cohort [26]. These dissimilarities are probably due to differences in BMI in early pregnancy, which was relatively lower in our sample (23 vs 30 on average), and to a different pregnancy week of assessment. When SBD was assessed by home sleep apnea testing device (montage reduced to breathing parameters), lower percentage values of SDB was reported [30].

The main limitations of our study are the lack of a control group of non-pregnant women and of postpartum follow-up polysomnographies. The strengths on the other hand are the prospective analysis of non-PSG data, the combination of subjective and objective data, and the size and homogeneity of the Life-ON study group.

In conclusion, EDS appears to prevail in the first trimester of pregnancy, whereas insomnia and an overall low quality of sleep are mainly represented in the first post-delivery phase. RLS and PLMS are frequent, with the first peak in the third trimester. Sleep macrostructure and the sleep-related breathing pattern appear to be only mildly affected by pregnancy.

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CRediT authorship contribution statement

Mauro Manconi: Conceptualization, Methodology, Writing – original draft, Supervision, Project administration, Funding acquisition. **Linda C. van der Gaag:** Software, Formal analysis, Data curation. **Francesca Mangili:** Software, Formal analysis, Data curation. **Corrado Garbazza:** Investigation, Project administration, Data curation. **Silvia Riccardi:** Central sleep scoring, Investigation. **Christian Cajochen:** Supervision. **Susanna Mondini:** Investigation, Supervision. **Francesca Furia:** Investigation. **Elena Zambrelli:** Investigation. **Simone Baiardi:** Investigation. **Alessandra Giordano:** Investigation. **Nicola Rizzo:** Supervision. **Cristina Fonti:** Ethic committee submission, Validation. **Elsa Viora:** Investigation. **Armando D'Agostino:** Conceptualization, Supervision, Writing – review & editing. **Alessandro Cicolin:** Conceptualization, Supervision. **Fabio Cirignotta:** Conceptualization, Supervision, Project administration, Funding acquisition, Writing – review & editing.

Declaration of competing interest

None.

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