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ORIGINAL RESEARCH

Insomnia and sleepiness during pregnancy: Associations with gestational diabetes mellitus

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Abstract

Introduction: Sleep quality typically deteriorates during pregnancy, and poor sleep is a risk factor for pregnancy complications, including gestational diabetes mellitus (GDM). The present study is the first longitudinal study addressing associations between sleep quality and GDM at separate time-points throughout the pregnancy.

Material and Methods: This study was a part of the FinnBrain cohort, including 3808 pregnant women. Sleep quality was assessed using the Basic Nordic Sleep Questionnaire four times during pregnancy, and GDM was diagnosed by glucose tolerance testing. Four groups were formed: non-GDM, GDM, and two subgroups of GDM (medical nutritional therapy and GDM with pharmacotherapy). Paired comparisons within the groups between different time-points were conducted, and cross-sectional logistic regression analyses were carried out. The results were adjusted by maternal age, body mass index, parity, education, smoking, mood symptoms, and pre-eclampsia.

Results: In paired comparisons between time-points, the insomnia score increased during pregnancy, albeit similarly in the GDM and non-GDM groups. However, the pattern of changes in sleepiness score differed between the groups during pregnancy. In the non-GDM group, mean scores showed a U-shape, decreasing in mid-pregnancy. This decrease was not observed in the GDM group, with scores remaining similar between early and mid-pregnancy and higher compared with the non-GDM group. These differences were more pronounced in the pharmacotherapy subgroup. In the cross-sectional analysis, only a few differences emerged between the groups. Women in the GDM group were more likely to report poor general sleep quality in mid-pregnancy compared with women in the non-GDM group (aOR 1.4, 95% CI 1.0–1.9,

Abbreviations: aOR, adjusted odds ratio; BMI, body mass index; BNSQ, Basic Nordic Sleep Questionnaire; CI, confidence interval; EPDS, Edinburgh Postnatal Depression Scale; GDM, gestational diabetes mellitus; OR, odds ratio; p^B, Bonferroni-corrected *p*-value; SCL-90, Symptom Checklist −90/Anxiety Scale.

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$p = 0.037$), but no differences in distinct insomnia symptoms emerged. Sleepiness symptoms were more common in the GDM group in early pregnancy (aOR 1.1, 95% CI 1.0–1.1, $p = 0.028$) and in mid-pregnancy (aOR 1.1, 95% CI 1.0–1.1, $p = 0.030$). Women in the GDM pharmacotherapy subgroup reported daytime napping more often in mid-pregnancy (aOR 1.8, 95% CI 1.0–3.3, $p = 0.049$).

Conclusions: Insomnia was found to increase as pregnancy proceeds, independently of GDM. However, the decrease in sleepiness found in women without GDM in mid-pregnancy was not observed in women with GDM, possibly indicating that the effectiveness of sleep is compromised in GDM patients.

KEYWORDS
gestational diabetes mellitus, insomnia, mother, pharmacotherapy, sleep quality, sleepiness, woman

1 | INTRODUCTION

Sleep problems increase during pregnancy,[1,2] most typically in late pregnancy.[3,4] Common sleep problems include insomnia symptoms, both initiation and maintenance insomnia,[3] as well as symptoms of sleepiness and fatigue.[3–5] Deterioration in sleep is caused by several factors, such as hormonal reasons, physio-anatomical changes, and alterations in mental state.[6,7]

Gestational diabetes mellitus (GDM) affects around 14% of pregnancies globally.[8] In Finland, in 2019, the GDM diagnosis level was 21% for expectant women,[9] but importantly, the incidence of GDM is constantly rising.[10,11] The main pathogenesis for GDM is β-cell dysfunction and insulin resistance.[12] Known risk factors include abnormal BMI (both under 18.5 kg/m^2 and over 25 kg/m^2), GDM in a previous pregnancy, a family history of type II diabetes, advanced maternal age, and polycystic ovarian syndrome.[12] However, the risk factors for GDM are likely multifactorial,[13] and therefore, additional investigation is required.

Maternal compromised sleep during pregnancy is associated with pregnancy complications.[14,15] Sleep problems may influence the onset of diabetes in several ways, including decreased glucose metabolism and elevated growth hormone and cortisol levels.[16,17] Despite these obvious connections, previous research on the association between GDM and sleep problems is sparse and conflicting. In two Chinese studies,[18,19] poor sleep quality in early pregnancy and, in a Singaporean study,[20] poor sleep quality in mid-pregnancy, were associated with increased risk for GDM. In the US study, however, no connection between sleep quality and the incidence of GDM was found.[21] In a Canadian study[22] there was no association between sleep quality and GDM incidence. Furthermore, previous studies have mostly been cross-sectional; only in a Chinese study[18] was sleep evaluated at two pregnancy measurement points and an Indian study[23] tracked sleep quality in different points of pregnancy but did not address whether specific time of pregnancy is more impactful.

Key message

Insomnia increases as pregnancy proceeds, but independently of gestational diabetes mellitus (GDM). However, the evolvement of sleepiness during pregnancy is different regarding GDM. Sleepiness is more common in women with GDM in early and mid-pregnancy, especially in women needing pharmacotherapy for GDM.

The aim of our study was to examine the association between maternal sleep quality and GDM in a longitudinal study design. We were especially interested in whether there is a critical time window between sleep problems and GDM. Further, in order to study sleep more in detail, we investigated various insomnia and sleepiness symptoms. We hypothesized that maternal sleep problems are associated with GDM and that more severe GDM, manifesting in the need for pharmacotherapy, is linked to more severe sleep problems.

2 | MATERIAL AND METHODS

This study was a part of the FinnBrain study, which is a prospective longitudinal birth cohort survey conducted in Turku University, Finland. The study design has been described in detail previously.[24] The study subjects were recruited during routine early pregnancy appointments by trained research nurses in the Turku and Åland hospital districts in Western Finland.

To be eligible, the women had to have adequate Finnish or Swedish skills for filling in the questionnaires. After being provided with information on the research study, volunteers signed a written consent form. To collect sleep quality information, the sleep questionnaires were sent in early pregnancy, mid-pregnancy, and late pregnancy either by post or by e-mail. If a response was not received,

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TABLE 1 Characteristic of the study subjects (total $n = 3738$).

	Non-GDM	GDM all		Medical nutritional subgroup	Pharmacotherapy subgroup	
	n = 3214	n = 524		n = 422	n = 102	
	Mean (range)	Mean (range)	p[a]	Mean (range)	Mean (range)	p[b]
Age	30 (17, 46)	31 (18, 44)	<0.0001	31 (18, 42)	31 (18, 44)	0.511
BMI						
Missing	23.12 (15.62, 60.61) na = 99	27.01 (17.56, 57.81) na = 1	<0.0001	26.53 (17.72, 57.81) na = 1	30.41 (17.56, 47.88)	<0.0001
	Number (%)	Number (%)	p	Number (%)	Number (%)	p
Parity			0.436			0.001
Nulliparous	1353 (42)	228 (44)		197 (47)	31 (30)	
Multiparous	1288 (40)	199 (38)		146 (35)	53 (52)	
Missing	573 (18)	97 (19)		79 (19)	18 (18)	
Education			0.032			0.916
Low	983 (31)	181 (35)		144 (34)	37 (36)	
Middle	765 (24)	126 (24)		101 (24)	25 (25)	
High	900 (28)	119 (23)		97 (23)	22 (22)	
Missing	566 (18)	98 (19)		80 (19)	18 (18)	
Pre-eclampsia			0.066			0.165
No	3129 (97)	502 (96)		407 (96)	95 (93)	
Yes	85 (3)	22 (4)		15 (4)	7 (7)	
Smoking			0.289			0.386
No	2680 (83)	428 (82)		341 (81)	87 (85)	
Yes	518 (16)	95 (18)		80 (19)	15 (15)	
Missing	16 (0)	1 (0)		1 (0)		

[a]Between non-GDM and GDM group.
[b]Between GDM nutritional therapy and GDM pharmacotherapy.

a reminder was sent twice via text message 2 and 3 weeks after the original questionnaire. Responses of ≥12 to <20 gestational weeks (gwks, mean 15 + 0 gwks, SD 1 + 1 gwks) were accepted as early pregnancy, of ≥20 to <30 gwks (mean 25 + 2 gwks, SD 1 + 2 gwks) as mid-pregnancy, and of ≥30 to ≤36 gwks (mean 34 + 6 gwks, SD 0 + 4 gwks) as late pregnancy data. Additionally, women filled in the same sleep questionnaire after delivery in the maternity ward, which was used as a delivery time-point. Delivery time-point answers were given in gwks of >36 to <43 (mean 40 + 0 gwks, SD 1 + 2 gwks).

A background information questionnaire was sent with the early pregnancy questionnaire, including questions on age (years), body mass index (BMI, kg/m^2), marital status (married/cohabited/divorced/single), parity (nulliparous/multiparous [number of children]), education (low/middle/high), and smoking status (yes/no). Possible depressive symptoms were assessed with the Edinburgh Postnatal Depression Scale (EPDS)[25,26] and anxiety symptoms with the Symptom Checklist-90/Anxiety Scale (SCL-90/anxiety scale).[27] In addition, the occurrence of pre-eclampsia during the present pregnancy was verified from patient records (yes/no). Altogether, 3808 women formed the cohort, of which 3738 women completed and returned at least one questionnaire and 1099 women completed and returned all four questionnaires in the accepted time window. Participant characteristics are described in Table 1.

Sleep quality in the previous month was assessed with the Basic Nordic Sleep Questionnaire (BNSQ),[28] including questions on general sleep quality and distinct insomnia and sleepiness symptoms. General sleep quality was assessed on a five-point scale from good to poor quality. Insomnia symptoms included difficulty falling asleep, frequency of nocturnal awakenings (separately both nightly and weekly), and waking up too early in the morning (without being able to fall asleep again). Sleepiness symptoms covered morning sleepiness, daytime sleepiness, and daytime napping. The five-point sleep variables were dichotomized to differentiate the severity of sleep problems. Answers ranging from “1” to “3” represented problems ≤2 nights/times per a week/night (no problem) and “4” or “5” ≥3 nights/times per week/night (problem).

Insomnia scores were calculated by adding up the rates for general sleep quality and insomnia symptoms of difficulty to fall asleep, frequency of nightly awakening (both nightly and weekly), and waking up too early in the morning (range 5–25). Sleepiness scores were calculated by adding up the rates for sleepiness symptoms of morning sleepiness, daytime sleepiness, and daytime naps (range 3–15).

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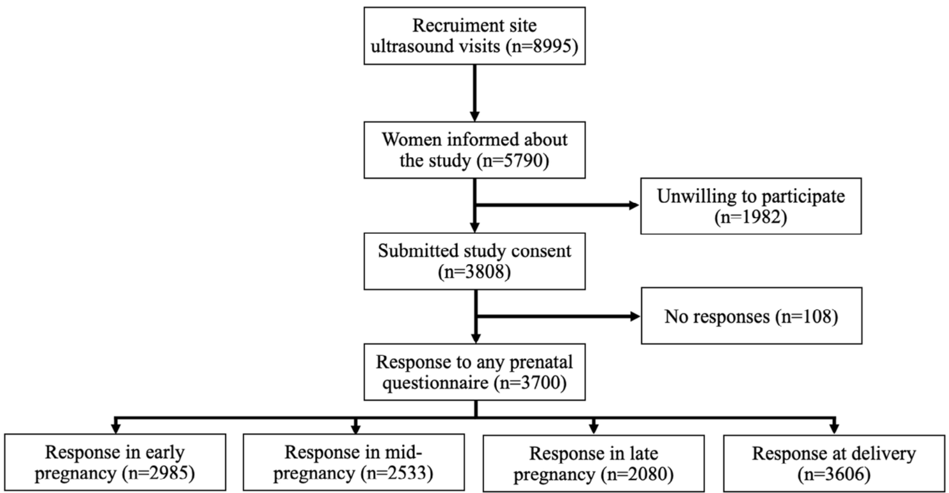

FIGURE 1 Flow chart of the study.

Higher scores both in insomnia and sleepiness scores indicated a higher occurrence of symptoms.

The women were screened for GDM according to the Finnish screening protocol. All women underwent glucose tolerance testing between gwk 24 and 28, unless they met the exclusion criteria of healthy BMI (18.5–24.9 kg/m^2) and no family history of diabetes, nullipara under 25 years of age, or multipara under 40 years of age with no diabetes in previous pregnancies. Women who were markedly obese (BMI ≥30 kg/m^2) or had known risk factors for GDM underwent glucose tolerance testing between gwk 12 and 16, and the standard test between gwk 24 and 28 if the first test was negative. Glucose tolerance testing was carried out using 75 g of glucose in a solution after fasting for 10–12 h. If the fasting blood glucose level was ≥5.3 mmol/L, the blood glucose level 1 h after glucose solution ingestion was ≥10 mmol/L, or the blood glucose level 2 h after glucose solution ingestion was ≥8.6 mmol/L, the women were diagnosed with GDM.

Once getting the GDM diagnosis, all patients received nutritional therapy. Pharmacotherapy was given for patients with two or more abnormal values (fasting value of ≥5.5 mmol/L or post-prandial value ≥7.8 mmol/L) within a 1-week period in follow-up despite following nutritional therapy that was given repeatedly at the appointments. In the present study, two groups were formed: women with a GDM diagnosis (GDM group; $n=524$) and women without a GDM diagnosis (non-GDM group; $n=3{,}214$). Furthermore, two GDM subgroups were formed according to the therapy provided: a GDM medical nutritional therapy group ($n=422$) and a GDM pharmacotherapy group ($n=102$).

2.1 | Statistical analysis

In paired comparisons between different time-points, the changes in both insomnia and sleepiness scores were evaluated using Wilcoxon's paired-sample rank test in each group separately: GDM all, medical nutritional therapy, pharmacotherapy, and non-GDM. *p*-values were corrected for multiple testing using Bonferroni correction. Changes were also examined visually with boxplots (Figure 2). In the event of one missing answer, the total score was created by substituting the missing value with the mean value of the answers of the same woman.

In the cross-sectional analysis, logistic regression was used at four time-points (early-, mid-, and late pregnancy, and delivery) and between the GDM group and the non-GDM group (unadjusted model, data not shown). Thereafter, the models were adjusted for age, BMI, parity, education, smoking, EPDS, SCL, and pre-eclampsia. Age, BMI, EPDS, and SCL were used as continuous and parity; education, smoking, and pre-eclampsia were used as categorical. Subsequently, both unadjusted and adjusted analyses were carried out comparing the two GDM subgroups (GDM medical nutritional therapy group and GDM pharmacotherapy group) to the non-GDM group. The results are expressed as odds ratios (ORs in unadjusted and aORs in adjusted models) with confidence intervals (95% CIs). *p*-values (two-tailed) of <0.05 were considered statistically significant. The significance levels in paired comparisons within the groups between different time-points were Bonferroni corrected and are indicated with p^B.

The analyses were conducted using R 4.2.2.[29] Figures were made with the ggplot2 package.[30]

3 | RESULTS

The distributions of the median and mean values in the insomnia and sleepiness scores for the four groups are shown in Figures 1 and 2 for all four pregnancy points. As a sign of sleep deterioration, insomnia scores increased between all consecutive time-points both in the non-GDM group (between early and mid-pregnancy $p^B=0.001$ and all other p^B-values <0.001) and in the GDM group (between early and mid-pregnancy $p^B=0.029$ and all other p^B-values <0.001). In the subgroup analysis, in the GDM medical nutritional therapy subgroup, insomnia scores increased between all consecutive time-points (between early and mid-pregnancy $p^B=0.033$ and all other p^B-values

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FIGURE 2 Insomnia and sleepiness score distributions (medians and quartiles) for non-GDM, GDM, and GDM medical nutritional therapy and GDM pharmacotherapy subgroups at four pregnancy time-points.

<0.001). In the GDM pharmacotherapy subgroup, insomnia symptoms did not change between early and mid-pregnancy (adj $p^B=1$) or between late pregnancy and delivery (adj $p^B=1$), but increased between other comparisons (early versus late, early versus delivery, mid versus late, mid versus delivery, all p^B-values <0.001).

Regarding the sleepiness scores, changes were observed in the non-GDM group: the sleepiness score decreased from early to mid-pregnancy ($p^B<0.001$) and increased from mid- to late pregnancy ($p^B<0.001$) and further from late pregnancy to delivery ($p^B<0.001$). In the GDM group, the sleepiness score did not differ in a similar manner between the consecutive time-points, but the differences between the two groups were non-significant (early versus mid $p^B=0.111$, mid versus late $p^B=1$, late versus delivery $p^B=0.811$). These findings were similarly non-significant in both GDM subgroup analyses: in the GDM medical nutritional subgroup (early versus mid $p^B=0.219$, mid versus late $p^B=1$, late versus delivery $p^B=0.281$) and in the pharmacotherapy subgroup (all $p^B=1$).

The results for general sleep quality at different time-points are shown in Tables 2–5. In the cross-sectional analysis, in early pregnancy, the majority of the women in both the non-GDM group and the GDM group reported good general sleep quality, at 85.5% and 86.4%, respectively. In the GDM subgroups, 86.9% of women in the GDM medical nutritional therapy subgroup and 84.2% of women in the GDM pharmacotherapy subgroup reported good general sleep quality. The frequencies in all GDM groups were similar compared with the non-GDM group. In mid-pregnancy, compared with the non-GDM group, women in the GDM group were more likely to report poor general sleep quality (adj $p=0.037$). Corresponding differences were not found when the subgroups were compared with non-GDM data. The frequencies of poor general sleep quality were over 25% in late pregnancy and over 40% at delivery in all groups, with no differences between the groups.

The results for insomnia symptoms at the different time-points are also shown in Tables 2–5. No difference was found in the insomnia scores between the non-GDM group and the GDM group at any of the pregnancy time-points. The same result was found in GDM subgroup comparisons with the non-GDM group. When assessed as distinct insomnia symptoms, nocturnal awakenings per week were the most frequent symptoms in both non-GDM and GDM groups at all pregnancy time-points. Already in early pregnancy over 74% in both groups reported these symptoms, and at delivery over 93% of women reported them, with no group differences.

Nocturnal awakenings per night were infrequent in early pregnancy, with a median of one nocturnal awakening in both the non-GDM and GDM groups. In late pregnancy, nocturnal awakenings become more common, with 75% of women in both groups reporting having them 1–4 times per night, with a median of two times. The GDM medical nutritional therapy subgroup did not differ from the non-GDM group, but the GDM pharmacotherapy subgroup had more nocturnal awakenings (adj $p=0.026$), with a median of three to four times per night in late pregnancy. At delivery, the awakenings became more common in all groups, and 75% of women reported 2–4 awakenings per night in both the non-GDM and GDM groups and in both GDM subgroups.

The frequencies in difficulty to fall asleep were also similar between the non-GDM groups and the GDM group, and in the subgroup analysis. In terms of too early morning awakening, the symptoms increased in all groups during pregnancy, although the increase was not as marked as in other insomnia symptoms. The women in the GDM group had a tendency for higher frequencies of the symptom in early pregnancy (adj $p=0.061$) but not at the other pregnancy time-points. In the subgroup analysis, too early morning awakenings were more common in mid-pregnancy in the GDM pharmacotherapy subgroup compared with the non-GDM group (adj $p=0.037$).

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AOGS Acta Obstetricia et Gynecologica Scandinavica

TABLE 2 Sleep disturbances in the groups in early pregnancy (total $n = 2985$).

			Non-GDM			GDM all				GDM medical nutritional therapy				GDM pharmacotherapy			
			$n = 2577$			$n = 408$				$n = 332$				$n = 76$			
	p[a]	p[b]	n (% of group)	Median (Q1, Q3)	OR	n (% of group)	Median (Q1, Q3)	AOR	95% CI	n (% of group)	Median (Q1, Q3)	AOR	95% CI	n (% of group)	Median (Q1, Q3)	AOR	95% CI
Insomnia																	
Insomnia score	0.217	0.135	2545	12 (10,15)		406	12 (10,15)	0.97	0.94–1.01	330	12 (10,14)	0.97	0.93–1.01	76	13 (10,15.25)	0.99	0.92–1.06
General sleep quality (continuous)	0.186	0.123	2544	2 (1, 3)	1	405	2 (1, 3)	0.76	0,53–1.07	329	2 (1, 3)	0.79	0.55–1.15	76	2 (1, 3)	0.62	0.30–1.28
Poor general sleep quality (categoric)	0.677		369 (14.5%)			55 (13,6%)				43 (13.1%)				12 (15.8%)			
Difficulty to fall asleep/week (continuous)	0.399	0.391	2540	1 (1, 2)	1	406	1 (1, 2)	1.22	0.76–1.89	330	1 (1, 2)	1.05	0.63–1.75	76	2 (1, 3)	1.98	0.90–4.35
Difficulty to fall asleep/week ≥3 nights/week (categoric)	0.181		147 (5.8%)			31 (7.6%)				21 (6.4%)				10 (13.2%)			
Nocturnal awakenings/ week (continuous)	0.718	0.104	2539	5 (4, 5)	1	405	5 (3, 5)	0.81	0.62–1.05	329	5 (3, 5)	0.80	0.60–1.05	76	5 (4, 5)	0.83	0.47–1.49
Nocturnal awakenings/ week ≥3 nights/ week (categoric)	0.206		1963 (77.3%)			301 (74.3%)				242 (73.6%)				59 (77.6%)			
Nocturnal awakenings/night (continuous)	0.884	0.731	2537	2 (2, 3)	1	405	2 (2, 3)	0.94	0.66–1.31	329	2 (2, 3)	0.85	0.58–1.25	76	2 (2, 3)	1.30	0.69–2.45
Nocturnal awakenings/night ≥3 times/night (categoric)	0.720		346 (13.6%)			52 (12.8%)				37 (11.2%)				15 (19.7%)			
Too early morning awakening/week (continuous)	0.987	0.061	2538	2 (1, 2)	1	404	2 (1, 2.25)	1.45	0.97–2.12	329	2 (1, 2)	1.50	0.99–2.28	75	2 (1, 3)	1.25	0.54–2.87
Too early morning awakening/week ≥3 nights/week (categoric)	0.068		182 (7.2%)			40 (9.9%)				33 (10.0%)				7 (9.3%)			

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TABLE 2 (Continued)

	p[a]	p[b]	Non-GDM			GDM all				GDM medical nutritional therapy				GDM pharmacotherapy			
			n = 2577			n = 408				n = 332				n = 76			
			n (% of group)	Median (Q1, Q3)	OR	n (% of group)	Median (Q1, Q3)	AOR	95% CI	n (% of group)	Median (Q1, Q3)	AOR	95% CI	n (% of group)	Median (Q1, Q3)	AOR	95% CI
Sleepiness																	
Sleepiness score	0.040	0.028	2546	8 (6,10)	1	405	8 (6,10)	1.05	1.01–1.10	329	8 (6,10)	1.04	0.99–1.09	75	9 (7,10)	1.11	1.01–1.22
Sleepiness at the morning/week (continuous)	0.228	0.149	2543	3 (2, 4)	1	403	3 (2, 4)	1.21	0.93–1.56	327	3 (2, 4)	1.17	0.88–1.54	76	3 (2, 4)	1.42	0.85–2.38
Sleepiness at the morning/week ≥3 days/week (categoric)	0.363		698 (27.4%)			120 (29.8%)				93 (28.4%)				27 (35.5%)			
Daytime sleepiness/week (continuous)	0.249	0.364	2540	3 (2, 4)	1	406	3 (2, 4)	1.12	0.87–1.44	330	3 (2, 4)	1.08	0.83–1.41	76	3 (2, 4)	1.32	0.80–2.20
Daytime sleepiness/week ≥3 days/week (categoric)	0.420		784 (30.9%)			134 (33%)				103 (31.2%)				31 (40.8%)			
Daytime napping/week (continuous)	0.032	0.258	2527	3 (2,3)	1	403	3 (2, 3)	1.17	0.89–1.53	328	3 (2, 3)	1.09	0.81–1.47	75	3 (2, 4)	1.64	0.95–2.81
Daytime nappings/week ≥3 days/week (categoric)	0.067		475 (18.8%)			92 (22.8%)				71 (21.6%)				21 (28.0%)			

[a]Value for median.

[b]Value for mean.

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TABLE 3 Sleep disturbances in the groups in mid-pregnancy (total $n = 2533$).

			Non-GDM			GDM all				GDM medical nutritional therapy				GDM pharmacotherapy			
			$n = 2165$			$n = 368$				$n = 291$				$n = 77$			
	p[a]	p[b]	*n* (% of group)	Median (Q1, Q3)	OR	*n* (% of group)	Median (Q1, Q3)	AOR	95% CI	*n* (% of group)	Median (Q1, Q3)	AOR	95% CI	*n* (% of group)	Median (Q1, Q3)	AOR	95% CI
Insomnia																	
Insomnia score	0.246	0.290	2138	13 (11,16)		364	13 (11,15)	1.02	0.98–1.06	288	13 (10,15)	1.02	0.98–1.06	76	13 (11,16)	1.02	0.94–1.10
General sleep quality (continuous)	0.339	0.037	2135	2 (2,3)	1	364	2 (2,3)	1.41	1.02–1.95	288	2 (2, 3)	1.39	0.97–1.98	76	2 (2, 3)	1.53	0.82–2.85
Poor general sleep quality (categoric)	0.004		315 (14.8%)			76 (20.9%)				59 (20.5%)				17 (22.4%)			
Difficulty to fall asleep/week (continuous)	0.417	0.282	2138	2 (1, 2)	1	363	2 (1, 2)	1.29	0.80–2.05	287	2 (1, 2.5)	1.12	0.65–1.92	76	2 (1, 2)	1.87	0.86–4.08
Difficulty to fall asleep/week ≥3 nights/week (categoric)	0.078		137 (6.4%)			33 (9.1%)				22 (7.7%)				11 (14.5%)			
Nocturnal awakenings/week (continuous)	0.072	0.481	2136	5 (4, 5)	1	363	5 (4, 5)	1.12	0.83–1.52	287	5 (4, 5)	1.08	0.78–1.49	76	5 (4, 5)	1.30	0.65–2.58
Nocturnal awakenings/week ≥3 nights/week (categoric)	0.306		1633 (76.5%)			287 (79.1%)				223 (77.7%)				64 (84.2%)			
Nocturnal awakenings/night (continuous)	0.842	0.782	2131	2 (2, 3)	1	363	2 (2, 3)	0.95	0.66–1.34	287	2 (2, 3)	0.83	0.56–1.24	76	3 (2, 3.25)	1.41	0.75–2.64
Nocturnal awakenings/night ≥3 times/night (categoric)	0.677		319 (15.0%)			58 (16.0%)				39 (13.6%)				19 (25.0%)			
Too early morning awakening/week (continuous)	0.282	0.182	2134	2 (1, 3)	1	363	2 (1, 3)	1.33	0.87–1.99	288	2 (1, 3)	1.15	0.72–1.84	75	2 (1, 3)	2.13	1.05–4.34
Too early morning awakening/week ≥3 nights/week (categoric)	0.104		166 (7.8%)			38 (10.5%)				26 (9.0%)				12 (16.0%)			

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TABLE 3 (Continued)

	p^a	p^b	Non-GDM			GDM all				GDM medical nutritional therapy				GDM pharmacotherapy			
			n = 2165			n = 368				n = 291				n = 77			
			n (% of group)	Median (Q1, Q3)	OR	n (% of group)	Median (Q1, Q3)	AOR	95% CI	n (% of group)	Median (Q1, Q3)	AOR	95% CI	n (% of group)	Median (Q1, Q3)	AOR	95% CI
Sleepiness																	
Sleepiness score	0.004	0.030	2551	8 (6, 10)		404	8 (6,10)	1.06	1.01–1.11	329	8 (6,10)	1.04	0.99–1.10	77	9 (7,10)	1.12	1.01–1.24
Sleepiness at the morning/week (continuous)	0.050	0.005	2134	3 (2, 3)	1	364	3 (2, 4)	1.49	1.12–1.97	288	3 (2, 4)	1.38	1.02–1.88	76	3 (2, 4)	2.02	1.17–3.48
Sleepiness at the morning/week ≥3 days/week (categoric)	0.002		515 (24.1%)			116 (31.9%)				85 (29.5%)				31 (40.8%)			
Daytime sleepiness/week (continuous)	0.145	0.992	2137	3 (2, 4)	1	364	3 (2, 4)	1.00	0.75–1.34	288	3 (2, 4)	1.02	0.74–1.40	76	3 (2, 4)	0.93	0.52–1.67
Daytime sleepiness/week ≥3 days/week (categoric)	0.499		542 (25.4%)			99 (27.2%)				78 (27.1%)				21 (27.6%)			
Daytime napping/week (continuous)	0.001	0.482	2124	2 (1, 3)	1	361	3 (2, 3)	1.13	0.80–1.57	285	3 (2, 3)	0.97	0.66–1.42	76	3 (2, 3.25)	1.83	1.00–3.33
Daytime nappings/week ≥3 days/week (categoric)	0.164		291 (13.7%)			60 (16.6%)				41 (14.4%)				19 (25.0%)			

[a]Value for median.

[b]Value for mean.

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TABLE 4 Sleep disturbances in the groups in late pregnancy (total $n = 2080$).

			Non-GDM			GDM all				GDM medical nutritional therapy				GDM pharmacotherapy			
			$n = 1787$			$n = 293$				$n = 229$				$n = 64$			
	p[a]	p[b]	n (% of group)	median (Q1, Q3)	OR	n (% of group)	median (Q1, Q3)	AOR	95% CI	n (% of group)	median (Q1, Q3)	AOR	95% CI	n (% of group)	median (Q1, Q3)	AOR	95% CI
Insomnia																	
Insomnia score	0.891	0.569	1773	15 (13,17)	1	290	15 (13,17)	0.99	0.95–1.03	226	15 (13,17)	0.97	0.92–1.02	64	16 (13,20)	1.06	0.98–1.15
General sleep quality (continuous)	0.811	0.356	1772	3 (2, 4)	1	290	3 (2,4)	0.86	0.63–1.18	226	2 (2, 4)	0.75	0.52–1.07	64	3 (2, 4)	1.39	0.77–2.53
Poor general sleep quality (categoric)	0.903		534 (30.1%)			89 (30.7%)				60 (26.5%)				29 (45.3%)			
Difficulty to fall asleep/week (continuous)	0.797	0.672	1772	2 (1, 3)	1	290	2 (1, 3)	1.08	0.75–1.54	226	2 (1, 3)	1.01	0.67–1.51	64	2 (1, 3.25)	1.34	0.69–2.60
Difficulty to fall asleep/week ≥3 nights/week (categoric)	0.301		295 (16.6%)			56 (19.3%)				40 (17.7%)				16 (25.0%)			
Nocturnal awakenings/week (continuous)	0.096	0.776	1772	5 (5, 5)	1	290	5 (5, 5)	0.93	0.56–1.61	226	5 (5, 5)	0.81	0.47–1.40	64	5 (5, 5)	2.19	0.47–10.15
Nocturnal awakenings/week ≥3 nights/week (categoric)	0.516		1642 (92.7%)			265 (91.4%)				204 (90.3%)				61 (95.3%)			
Nocturnal awakenings/night (continuous)	0.581	0.987	1771	3 (2, 4)	1	289	3 (2, 4)	1.00	0.74–1.33	225	3 (2, 4)	0.83	0.60–1.15	64	4 (2.75, 4)	1.91	1.08–3.39
Nocturnal awakenings/night ≥3 times/night (categoric)	0.552		602 (34.0%)			104 (36.0%)				71 (31.6%)				33 (51.6%)			
Too early morning awakening/week (continuous)	0.871	0.630	1769	2 (1, 3)	1	290	2 (1, 3)	1.10	0.73–1.63	226	2 (1, 3)	1.04	0.67–1.63	64	2 (1, 3)	1.34	0.64–2.80
Too early morning awakening/week ≥3 nights/week (categoric)	0.122		208 (11.8%)			44 (15.2%)				32 (!4.2%)				12 (18.8%)			

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TABLE 4 (Continued)

	p[a]	p[b]	Non-GDM			GDM all				GDM medical nutritional therapy				GDM pharmacotherapy			
			n = 1787			n = 293				n = 229				n = 64			
			n (% of group)	median (Q1, Q3)	OR	n (% of group)	median (Q1, Q3)	AOR	95% CI	n (% of group)	median (Q1, Q3)	AOR	95% CI	n (% of group)	median (Q1, Q3)	AOR	95% CI
Sleepiness																	
Sleepiness score	0.853	0.300	1773	8 (6,10)		290	8 (6,10)	0.97	0.92–1.03	226	8 (6,10)	0.95	0.90–1.01	64	9 (7,11)	1.06	0.95–1.18
Sleepiness at the morning/week (continuous)	0.687	0.915	1770	3 (2, 3)	1	290	2 (2, 3)	0.98	0.69–1.38	226	2 (2, 3)	0.84	0.56–1.25	64	3 (2, 4)	1.52	0.81–2.84
Sleepiness at the morning/week ≥3 days/week (categoric)	0.303		382 (21.6%)			71 (24.5%)				47 (20.8%)				24 (37.5%)			
Daytime sleepiness/week (continuous)	0.722	0.826	1769	3 (2, 4)	1	289	3 (2, 4)	1.04	0.75–1.42	225	3 (2, 4)	1.04	0.73–1.47	64	3 (2, 4)	1.01	0.54–1.87
Daytime sleepiness/week ≥3 days/week (categoric)	0.623		504 (28.5%)			87 (30.1%)				64 (28.4%)				23 (35.9%)			
Daytime napping/week (continuous)	0.580	0.372	1763	3 (2, 3)	1	290	3 (2, 3)	0.86	0.61–1.19	226	3 (2, 3)	0.78	0.54–1.13	64	3 (2, 4)	1.19	0.65–2.20
Daytime nappings/week ≥3 days/week (categoric)	0.609		423 (24.0%)			65 (22.4%)				45 (19.9%)				20 (31.2%)			

[a]Value for median.

[b]Value for mean.

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TABLE 5 Sleep disturbances in the groups at delivery (total $n=1976$).

			Non-GDM			GDM all				GDM medical nutritional therapy				GDM pharmacotherapy			
			$n=1680$			$n=296$				$n=239$				$n=57$			
	p[a]	p[b]	n (% of group)	median (Q1, Q3)	OR	n (% of group)	median (Q1, Q3)	AOR	95% CI	n (% of group)	median (Q1, Q3)	AOR	95% CI	n (% of group)	median (Q1, Q3)	AOR	95% CI
Insomnia																	
Insomnia score	0.401	0.164	1453	16 (14, 19)	1	288	16 (13,19)	0.97	0.93–1.01	234	16 (13.5,18.5)	0.96	0.92–1.00	54	16 (13,20)	1.03	0.94–1.12
General sleep quality (continuous)	0.636	0.780	1664	3 (2, 4)	1	341	3 (2, 4)	0.96	0.73–1.26	276	3 (2, 4)	0.90	0.67–1.21	65	3 (2, 4)	1.33	0.75–2.36
Poor general sleep quality (categoric)	0.705		686 (41.2%)			144 (42.2%)				113 (40.9%)				31 (47.7%)			
Difficulty to fall asleep/week (continuous)	0.212	0.205	1666	3 (2, 4)	1	343	3 (2, 3.5)	0.82	0.61–1.11	278	3 (2, 4)	0.77	0.56–1.07	65	2 (1, 3)	1.09	0.59–2.02
Difficulty to fall asleep/week ≥3 nights/week (categoric)	0.538		475 (28.5%)			93 (27.1%)				75 (27.0%)				18 (27.7%)			
Nocturnal awakenings/week (continuous)	0.967	0.402	1668	5 (5, 5)	1	343	5 (5, 5)	0.78	0.45–1.43	278	5 (5, 5)	0.69	0.38–1.23	65	5 (5, 5)	2.24	0.30–16.78
Nocturnal awakenings/week ≥3 nights/week (categoric)	0.960		1585 (95.0%)			324 (94.5%)				262 (94.2%)				62 (95.4%)			
Nocturnal awakenings/night (continuous)	0.811	0.577	1663	3 (3, 4)	1	342	3 (3, 4)	0.93	0.71–1.21	277	3 (3, 4)	0.85	0.64–1.12	65	4 (3, 4)	1.45	0.81–2.58
Nocturnal awakenings/night ≥3 times/night (categoric)	0.962		789 (47.4%)			165 (48.2%)				127 (45.8%)				38 (58.5%)			
Too early morning awakening/week (continuous)	0.507	0.811	1667	2 (2, 3)	1	341	2 (2, 3)	0.96	0.68–1.33	276	2 (2, 3)	0.89	0.61–1.28	65	3 (1, 3)	1.38	0.71–2.69
Too early morning awakening/week ≥3 nights/week (categoric)	0.816		302 (18.1%)			65 (19.1%)				51 (18.5%)				14 (21.5%)			

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TABLE 5 (Continued)

	p^a	p^b	Non-GDM n=1680			GDM all n=296				GDM medical nutritional therapy n=239				GDM pharmacotherapy n=57			
			n (% of group)	median (Q1, Q3)	OR	n (% of group)	median (Q1, Q3)	AOR	95% CI	n (% of group)	median (Q1, Q3)	AOR	95% CI	n (% of group)	median (Q1, Q3)	AOR	95% CI
Sleepiness																	
Sleepiness score	0.513	0.944	1670	9 (7,10)	1	341	9 (7,10)	1.00	0.95–1.05	276	9 (7,10)	0.99	0.94–1.04	65	9 (7, 11)	1.07	0.97–1.19
Sleepiness at the morning/week (continuous)	0.766	0.631	1670	3 (2, 3)	1	341	3 (2, 3)	1.08	0.78–1.48	276	3 (2, 3)	1.02	0.72–1.45	65	3 (2, 4)	1.39	0.75–2.59
Sleepiness at the morning/week ≥3 days/week (categoric)	0.322		354 (21.2%)			82 (24.0%)				63 (22.8%)				19 (29.2%)			
Daytime sleepiness/week (continuous)	0.528	0.606	1669	3 (2, 4)	1	341	3 (2, 4)	1.08	0.81–1.44	276	3 (2, 4)	1.01	0.74–1.38	65	3 (2, 4)	1.48	0.82–2.65
Daytime sleepiness/week ≥3 days/week (categoric)	0.369		466 (27.9%)			105 (30.8%)				82 (29.7%)				23 (35.4%)			
Daytime napping/week (continuous)	0.430	0.432	1661	3 (2, 4)	1	340	3 (2, 4)	0.90	0.68–1.18	277	3 (2, 4)	0.85	0.63–1.14	63	3 (2, 4)	1.16	0.65–2.08
Daytime nappings/week ≥3 days/week (categoric)	1.0		601 (36.2%)			123 (36.2%)				96 (34.7%)				27 (42.9%)			

[a]Value for median.

[b]Value for mean.

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The results for sleepiness symptoms at different time-points are shown in Tables 2–5. Compared with the non-GDM group, the sleepiness score was higher in the GDM group in early (adj $p=0.028$) and in mid-pregnancy (adj $p=0.030$) but not in late pregnancy or at delivery. In the GDM subgroup analysis, the GDM medical nutritional therapy subgroup did not show differences to the non-GDM group at any time-points. In the GDM pharmacotherapy subgroup, the sleepiness score was higher in early (adj $p=0.029$) and mid-pregnancy (adj $p=0.027$). Of the distinct sleepiness symptoms, daytime sleepiness was the most common symptom in early and late pregnancy in the GDM group and the most common in early, mid-, and late pregnancy in the non-GDM group. Daytime napping was the least common symptom in the GDM and the non-GDM groups in early and mid-pregnancy, but at delivery, it was the most common sleepiness symptom in both groups.

Women in the GDM group were more likely than those in the non-GDM group to have morning sleepiness in mid-pregnancy (adj $p=0.005$). The same result was found for both GDM subgroups (adj $p=0.039$ for the GDM medical nutritional subgroup and adj $p=0.011$ for the GDM pharmacotherapy subgroup). There were no other differences in sleepiness symptoms between the GDM and non-GDM groups, but the women in the GDM pharmacotherapy subgroup were more likely than the women in the non-GDM group to have daytime napping in mid-pregnancy (adj $p=0.049$).

4 | DISCUSSION

In our follow-up study, we found that insomnia increased as pregnancy proceeded, but independently of GDM. Similarly, general sleep quality worsened during pregnancy in all groups, but the women with GDM were more likely to report poor general sleep quality in mid-pregnancy compared to the women without GDM. Regarding distinct insomnia symptoms, the differences between the GDM and non-GDM groups were marginal. Nocturnal awakening, assessed on a weekly basis, was the most frequent symptom in all groups. However, the evolvement of sleepiness during pregnancy was different between the GDM and non-GDM groups. The decrease in sleepiness shown in mid-pregnancy in the non-GDM group was not found in women with GDM. In the GDM group, sleepiness did not change between early and mid-pregnancy and was also marginally higher at both pregnancy points compared to women without GDM. This finding was especially apparent in the GDM pharmacotherapy subgroup. As in distinct insomnia symptoms, the differences in distinct sleepiness symptoms between the GDM and non-GDM groups were minor.

Our results contradict those of a previous Chinese study[18] in which sleep quality in 4,066 pregnancies was evaluated twice, in early and mid-pregnancy. In that study, poor sleep quality in early pregnancy but not in mid-pregnancy was associated with higher risk for GDM, while we found an opposite association. Of note is that in their study, the early pregnancy sleep was assessed retrospectively in mid-pregnancy, whereas we evaluated sleep quality during the restricted time-points, which possibly at least partly explained the differences. Another Chinese study[19] with 1216 pregnant women also found a connection between early pregnancy sleep quality and GDM, a finding, which we could not confirm. The study designs were alike, but that study was conducted in a lower latitude than our study. Mid-pregnancy poor sleep quality has previously been shown to be associated with higher fasting blood glucose levels in a Singaporean study of 686 women.[20]

Insomnia symptoms may lead to sleep deprivation,[31] which has been shown to be linked to diabetes mellitus (DM) in non-pregnant patients at least via growth hormone and cortisol levels.[16] Accordingly, one could hypothesize a similar connection between insomnia symptoms during pregnancy and GDM. To best of our knowledge, only one previous cross-sectional study has evaluated this connection.[21] In the study from the US, a cohort of 307 women showed no increased risk for GDM associated with insomnia symptoms. Similarly, in our cross-sectional analysis including four different pregnancy time-points, we could find practically no associations between distinct insomnia symptoms and GDM.

Daytime sleepiness has many causes, including insufficient sleep, poor sleep quality, sleep-disordered breathing, and circadian disorders.[32] In the general population, sleepiness has strongly shown to be associated with diabetes.[33] As for the connection between maternal sleepiness during pregnancy and GDM, previous literature is sparse. A cross-sectional US study of 1,588 women recruited in the third trimester[34] found no association between sleepiness symptoms and GDM. In that study, the diagnosis of GDM was made before the assessment of sleepiness. Contrary to this, in a Chinese study of 1,402 women,[35] sleepiness was related to both GDM and pre-pregnancy DM. Similar to the US study, sleepiness was assessed in late pregnancy after establishing the GDM diagnosis. In our study, in the cross-sectional analysis, women in the GDM group were marginally more likely to have higher sleepiness scores both in early and mid-pregnancy, before GDM was diagnosed in most of the women. In addition, the development of sleepiness symptoms during pregnancy differed between the GDM and non-GDM groups. Sleepiness lessened in mid-pregnancy in the non-GDM group, but a similar decrease was not found in the GDM group or in the GDM subgroups. One possible cause for our finding could be existence of sleep-disordered breathing, which has been linked to both sleepiness and GDM.[33,36,37] Another connective factor could be cytokine concentrations, which have been shown to be associated with tiredness and differ between healthy individuals and patients with diabetes.[38,39]

Our study was the first conducted in high Northern latitude with considerable seasonal variation in daylight time. Furthermore, in Finland, a seasonal effect is considerable. In winter, the diurnal light time is extremely short, whereas in summer, the days are mainly light. The enrollment of the women in our study took place throughout the year. Therefore, some women entered the study in winter and the others in summer. This seasonal change, along with a phase delay of circadian rhythms, could have interfered with our results. This at

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least to some extend made it difficult to compare our results with previous studies conducted in other latitudes with stable diurnal lightness throughout the year. However, our results concur with a Canadian case control study conducted closer to our latitude showing no correlation between sleep quality and GDM. Furthermore, socio-economic conditions and lifestyle are also likely to have an effect on sleep.[5,40] In general, studies from Global North seem to match our results better than studies from countries with lower income levels.

The strengths of our study include a large sample size and a relatively high response rate. In Finland, GDM screening is conducted for all women at risk in maternity healthcare clinics, free of charge and attended by practically all pregnant women[41,42] In the Finnish medical system, all GDM diagnoses are reported in a structured manner on the electronic medical record. We used this information, and thus, the GDM diagnosis information could be considered reliable. As several insomnia and sleepiness symptoms were assessed at different time-points of the pregnancy, we were able to evaluate the occurrence of symptoms throughout the pregnancy and their connection to GDM. However, as we did not evaluate sleep quality before pregnancy, possible pre-pregnancy differences in sleep between the groups could not be assessed. Sleep hygiene, which could have offered an additional way of addressing risk factors for poor sleep quality,[19] was not assessed in our study.

Self-report questionnaires for data collection carry both positive and negative factors. This method allowed us to form a large sample size and lowered the threshold of participation. The questionnaire utilized has been validated[28] and is commonly used in studies with pregnant women.[4,43] It permitted a detailed sleep evaluation, distinguishing various insomnia and sleepiness symptoms. Despite a detailed sleep evaluation, we did not collect any objectively measured sleep data. There is a known difference between objectively measured sleep quality and subjectively evaluated sleep quality. This mismatch can be explained at least by the different time frames of evaluation: Polysomnography evaluates sleep during one or at most several nights, while questionnaires are used to evaluate sleep over a longer period—in our study, a previous month. Previous studies have shown that subjective sleep quality is usually sufficient and can be more predictive for realization of risks than objective evaluation.[44,45] The sleep questionnaire we used was available only in Finnish or Swedish, the official languages in Finland, and therefore, the women without these language skills presumably did not take part in the study. However, at the time the recruitment took place, the majority of the population in Finland are Finnish or Swedish speaking,[46] and thus, this issue was not likely to cause a significant bias.

5 | CONCLUSION

Our study reaffirmed that insomnia increases and sleep quality worsens during pregnancy. However, this worsening was found to be independent of GDM. Sleepiness was showed to be more common in women with GDM in early and mid-pregnancy, especially in women needing pharmacotherapy for GDM. These findings were novel. Our results may indicate that although no differences were discovered in the occurrence of insomnia symptoms, sleep was not refreshing enough in GDM patients. In future studies, addressing possible contributory factors for these findings, including the effects of sleep disorders such as sleep-disordered breathing as well as sleep deprivation in GDM patients, is warranted.

AUTHOR CONTRIBUTIONS

OF is the principal investigator and writer of the paper. PP-K is the leader and co-writer of the present study. EJP, LA, IM, and SR are the co-investigators in the present study. LP is the statistician of the study. LK and HK are the leaders of the FinnBrain study. EJP is the principal investigator of the sleep studies in the Finnbrain study.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from FinnBrain research. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the author(s) with the permission of FinnBrain research.

ETHICAL STATEMENT

The study had the approval of the Joint Ethics Committees of the University of Turku and Turku University Hospital, Turku, Finland (number 8/180/2010). 57/180/2011 on June 14, 2011, § 168.

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