Peer Community Journal

Section: Health & Movement Sciences

Research article

Published
2025-08-29

Cite as
Aleksandra Ciochoń, Łukasz Balwicki, Magdalena Klimek, Dariusz P. Danel, Anna Apanasewicz, Anna Ziomkiewicz, Andrzej Galbarczyk and Urszula M. Marcinkowska (2025) *Cigarette smoke exposure as a potential risk factor for sleep problems in pregnant women*, Peer Community Journal, 5: e90.

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Peer-review
Peer reviewed and recommended by PCI Health & Movement Sciences, https://doi.org/10.24072/pci.healthmovsci.100117

Cigarette smoke exposure as a potential risk factor for sleep problems in pregnant women

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Volume **5** (2025), article e90

https://doi.org/10.24072/pcjournal.621

Abstract

Cigarette smoking and exposure to cigarette smoke during pregnancy have detrimental effects on the health of expectant mothers, increasing the likelihood of respiratory diseases or infections. Due to the stimulant effect of smoking, the negative effect on diurnal rhythm and sleep is also observed. Sleep quantity and quality are directly related to health and well-being, especially during times of excess stress, such as the perinatal period. This prospective study aimed to examine the relationship between cigarette smoking and exposure to cigarette smoke during pregnancy and sleep patterns in pregnant women. An online survey was conducted among Polish women from May 2020 to September 2021, during the COVID-19 pandemic. Participants reported smoking during pregnancy and rated sleep in three categories (difficulty falling asleep, waking up too early, and difficulty staying asleep). Data from 3365 mothers aged 18-43 (mean 30.7; SD 3.87) were analyzed using multivariate logistic regression. Passive smoking was associated with one of the three variables used to assess sleep problems (waking up too early) while controlling for a range of individual variables (age, education, place of residence, satisfaction with the woman's life, and economic situation, pregnancy complications, levels of state anxiety and depressive symptoms, trimester of pregnancy, nausea or vomiting during pregnancy, and COVID-19 infections). Interestingly, results showed no evidence of an association between active smoking and sleep difficulties. Our findings suggest that passive smoking is a potential risk factor for sleeping problems in pregnant women, especially in the aspect of waking up too early. These results are worth considering when formulating pro-health measures for pregnant women and their close ones.

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Peer Community Journal is a member of the Centre Mersenne for Open Scientific Publishing
http://www.centre-mersenne.org/

e-ISSN 2804-3871

Web-published in collaboration with UGA Éditions

Introduction

Sleep is an essential physiological need for humans, as it is one of the necessities for survival in Maslow's hierarchy of needs. Sufficient sleep is crucial for maintaining good overall health and achieving higher life goals (Taormina & Gao, 2013). From a biological standpoint, sleep plays a vital role in regulating hormones, cognitive functions, and the immune system's performance, aiding the body in fighting pathogens, both in men and women (Alimoradi et al., 2022a; Besedovsky et al., 2019). According to the National Sleep Foundation, adults between the ages of 18 and 64 should aim for 7 to 9 hours of sleep per night (Chaput et al., 2020). Studies indicate that sleep problems are increasingly common, especially among women, who are more likely than men to report sleep difficulties, with one-third of women not getting enough sleep, particularly during pregnancy (Delgado & Louis, 2022). This can be due to existing differences in diurnal rhythms between men and women, as well as hormonal and emotional changes during pregnancy (Lord et al., 2014, Delgado & Louis, 2022). Moreover, an analysis of Polish pregnant women revealed that over 75% experienced sleep problems such as nighttime awakening (over 52%) or insomnia (about 20%), particularly during the third trimester of pregnancy (Smyka et al., 2020).

The period of pregnancy is associated with the occurrence of many physiological changes in the body, related to the development of the fetus and the preparation of the women's body for future motherhood. Numerous modifications in the physiological processes occurring within the woman's body lead to pregnancy discomfort, such as headaches, frequent diarrhea, fainting, nausea or irritability, and mood swings (Kamysheva et al., 2009; Soma-Pillay et al., 2016). Also, not to be overlooked are variations in the quality, duration, and pattern of sleep and the resulting disorders. According to a study published by Reid et al. in 2017, 30% of the pregnant women slept <7 hours per night (2.6% slept more than 9 hours per night), and as the pregnancy progressed, the quality and length of sleep deteriorated (Reid et al., 2017). In addition, it has been shown that more than 11% of women suffer from insomnia or too little sleep duration during pregnancy (Paavonen et al., 2017). These are particularly worrisome data, as insufficient sleep in the second and third trimesters of pregnancy is associated with an increased risk of pre-eclampsia and preterm labor (Gupta & Rawat, 2020). In addition, insomnia in the third trimester increases the chances of perinatal complications by, among other things, increasing the duration of labor (Liamsombut & Tantrakul, 2022; Gupta & Rawat, 2020; Yang et al., 2024; Danilov et al., 2022). Moreover, sleep deprivation during pregnancy is a predictor of gestational diabetes, hypertensive disorders, and excessive weight gain (O'Keeffe & St-Onge, 2013). Furthermore, a lack of sleep can cause heightened emotional tension and susceptibility to stress, making it difficult to maintain mental well-being (Gupta & Rawat, 2020; Yang et al., 2024; Danilov et al., 2022).

The causes of sleep abnormalities during pregnancy should not be found only in physiological changes that occur during pregnancy and the resulting pregnancy discomforts (Perz et al., 2006). Psychological changes, unhealthy habits, and external factors are worth considering. The thought of the hardships of motherhood, worries about childbirth or daily worries can cause restless sleep, frequent waking at night, or insufficient sleep duration (Hamułka et al., 2018). Moreover, the mother-to-be behavior, that is, insufficient physical activity, unhealthy diet, and lack of social support, negatively affect not only sleep but also the comfort of her life (Sanchez et al., 2020; Żyrek et al., 2024). In addition to all other issues, the COVID-19 pandemic and the related restrictions (Alimoradi et al., 2021), i.e. uncertainty of the future, and limited access to medical care, have further burdened expectant mothers (Jahrami et al., 2021), contributing to numerous health and psycho-emotional problems and the need to find a way to cope with them (Ahlers-Schmidt et al., 2020; Żyrek et al., 2024). A meta-analysis published by Alimoradi et al. in 2022, presenting data collected between December 2020 and July 2021, found that pregnant women experienced a significant decrease in sleep quality (of about 13%), during the COVID-19 pandemic noting that the short- and long-term consequences of such sleep changes in pregnancy and offspring outcomes are unclear and require further research (Alimoradi et al., 2022b).

In some cultures, cigarette smoking may be considered a way to unwind, forget traumatic experiences, cope with stress, or, paradoxically, improve sleep quality (Bacaro et al., 2020; Braun et al., 2012; Safa et al., 2020). This is worrisome, noting the occurrence of smoking in pregnant women. According to available data, about 7-8% of pregnant women in Poland smoke (Wojtyła & Wojtyła-Buciora, 2017), while globally the prevalence ranges between 10-15% (Lange et al., 2018). It has been observed that children born to mothers who smoke or are exposed to smoking, especially cotinine (the main metabolite of nicotine, which penetrates the fetal circulation), are characterized by low birth weight, suffer birth defects, or reduced intrauterine growth (Perz et al., 2006; Hamułka et al., 2018; Law et al., 2003; Cowperthwaite et al. 2007; Donnenfeld et al., 1993), and may exhibit greater excitability and increased muscle tone in infancy (Stroud et al., 2020).

Smoking, but also exposure to smoke (passive smoking also known as second-hand smoking, refers to the involuntary inhalation of smoke from cigarettes or other tobacco products by nonsmokers) are likely causes of sleep disorders (Nelson, 2001, Safa et al., 2020; Yang et al., 2023; O'Callaghan et al., 2019). Probably, this is due to the presence of nicotine, which is found in tobacco and is one of the substances that addicts and stimulates the nervous system. It also affects neurochemical processes related to sleep, such as the stimulation of cholinergic neurons, which can cause physiological arousal (Falup-Pecurariu et al., 2021). This arousal can adversely affect the quality and sleep duration (Safa et al., 2020; Yang et al., 2023; O'Callaghan et al., 2019). Additionally, nicotine can affect the release of neurotransmitters, such as dopamine, serotonin, and acetylcholine, which are responsible for normal diurnal rhythms and can cause sleep disturbances (Safa et al., 2020; Blalock et al., 2013). Smoking probably also increases the risk of other smoking-related diseases such as obstructive sleep apnea (OSA), which affects the ability to breathe freely during sleep (Pataka et al., 2022). Additionally, the adverse effects of smoking on sleep quality were confirmed in smokers, among whom smoking exposure was measured using a biomarker in urine (1- hydroxypyrene). Active smokers who exhibited high levels of this biomarker reported poorer sleep quality and impaired daytime functioning (Zhou et al., 2018). A small number of controversial studies conducted among pregnant smokers also confirmed the prevalence of sleep abnormalities, indicating its prevalence and the need to further study this issue (Paavonen et al., 2017; Danilov et al., 2022; Lange et al., 2018; Popova et al., 2017; Andres & Day, 2000). Additionally, as insufficient sleep negatively affects smoking cessation (Sanchez et al., 2020), women who failed to decrease smoke exposure during pregnancy can further deteriorate their sleep quality – creating a positive reinforcement loop making it harder to limit smoke exposure in the future.

This study aimed to investigate the relationship between active smoking and the occurrence of sleep problems, such as difficulty falling asleep, maintaining sleep, and waking up too early among mothers-to-be. Additionally, this study evaluated the relationship between second-hand exposure to cigarette smoke and the occurrence of the aforementioned sleep problems. We hypothesized that smoking exposure (active and passive) of pregnant women will increase their chance of sleep problems during gestation manifested by shortened sleep duration, difficulty falling asleep, and frequent awakenings during the night. We believe that the different approaches published in the other articles, the analysis of sleep dysfunctions (division into 3 different categories), and the unique pandemic context add value to the article, which will allow to gain another portion of knowledge about the studied issue.

Material and methods

Study group

The current analysis is a part of the prospective Corona Mums project which aimed to expand knowledge on the impact of women's well-being on pregnancy and their child's intrauterine and postnatal development (https://osf.io/5cveq/). Adult women who were pregnant or had become pregnant during the introduction of restrictions caused by the COVID-19 pandemic (from May 2020 to September 2021) in Poland were invited to participate in the study. The participants (convenience sample) were recruited through social media, local radio broadcasts, newspapers,

and websites dedicated to pregnant women. The exclusion criteria for the analysis were multiple pregnancies and major complications during pregnancy, such as the presence of genetic and developmental defects of the child, metabolic diseases of the mother, such as diabetes or thyroid gland diseases, and the pregnant woman's use of alcohol and other addictive substances during pregnancy. Due to the prevailing epidemiological conditions, the study was conducted online and was restricted to one submission per device.

Participants provided basic sociodemographic information, such as age, education, place of residence, assessment of life satisfaction and financial situation, and information about their health status and pregnancy details (including trimester of pregnancy, occurrence of pregnancy complications such as anemia, gestational diabetes, gestational hypertension, gestational thyroid diseases, nausea or vomiting, COVID-19 infections, assessment of anxiety level, and depression). The level of anxiety and depression was assessed based on the Polish adaptation of the State-Trait Anxiety Inventory - STAI, on a scale of 20-80 (Sosnowski et al., 2011, Spielberger, 1983), and the Polish adaptation of the Edinburgh Postnatal Depression Questionnaire - EPDS, on a scale of 0-30 (Kossakowska, 2013).

The study involved 3365 pregnant women from different parts of Poland, aged 18 to 43 years (M = 30.7, SD = 3.87). The majority of the participants had a university degree (at least a bachelor's degree; 78.7%), reported experiencing pregnancy-related complaints, such as nausea or vomiting (62.2%), complications during pregnancy (77%), and had not contracted the SARS-CoV-2 virus (86.8%) at the time of survey completion. Of the pregnant women, 50.7% were in their third trimester of pregnancy. Correlations between smoking status and demographic/psychological variables are available in supplementary materials (Supplementary Materials 1).

A significant percentage of women (63.6%) experienced difficulties falling asleep, while 75% struggled to stay asleep and 63.5% reported early morning awakenings that led to inadequate sleep. In terms of substance use during pregnancy, 6.2% of women smoked, and 15.5% were exposed to secondhand smoke (passive smoking). Table 1 presents the descriptive statistics of the participants. In supplementary materials are accessible the univariate associations between smoking status and sleep (Supplementary Materials 2).

The research followed the guidelines of the Bioethics Committee of the Jagiellonian Universitywith opinion number 1072.6120.141.2020, dated 28/05/2020, and 1072.6120.359.2020, dated 16/12/2020. All the participants provided informed consent and were informed of their right to resign from the survey at any given point without any negative repercussions.

Sleep problems and smoking use assessment

To assess the use of smoking and the extent of women's exposure to cigarette smoke from traditional and electronic cigarettes (passive smoking), pregnant women were queried about smoking cigarettes during pregnancy (yes/no) and smoking in their immediate surroundings (yes/no). Sleep problems were self-reported in 3 categories: difficulties in falling asleep (yes/no), waking up too early (yes/no), and difficulties in maintaining sleep (yes/no).

Statistical analysis

Multivariate logistic regression models were used to determine the association between active and passive smoking during pregnancy, and the occurrence of sleep difficulties in pregnant women. Each aspect of sleep difficulties and smoking : active smoking (no=0 vs. yes=1), and passive smoking (no=0 vs. yes=1), was analyzed in separate models with 3 variables describing sleep issues (6 models in total, with "Model 1" referred to active smoking, while "Model 2" referred to passive smoking). The presence of sleep issues constituted the reference group in the models (no sleep problems=0 vs. presence of sleep problems=1), and the complete dataset for each participant was used for analysis. Control variables were selected based on available literature describing the risk factors for sleep problems in pregnant women. Among the control variables, we included age (in years) (Delgado & Louis, 2022; Andres & Day, 2000), satisfaction with life, and financial situation (subjective rating on a scale of 1-7) (Cai et al., 2022), trimester of pregnancy

(dummy-coded, where trimester 1st was the reference level to trimester 2nd and trimester 3rd respectively), the occurrence of pregnancy complications (no=0 vs. yes=1), complaints of nausea or vomiting (no=0 vs. yes=1) (Liamsombut & Tantrakul, 2022; Sanchez et al., 2020), state of anxiety as score and level of depression. In addition, each model presented had several control variables such as education (lower than tertiary education=0 vs. tertiary education=1) and place of residence (city<100,000 residents=0 vs. city>100,000 residents=1) (Cai et al., 2022; Kempler et al., 2012; Mezick et al., 2008). Since the project was conducted during the pandemic period, the fact that a pregnant woman had COVID-19 (no=0 vs. yes=1) was also included in the analyses (Cai et al., 2022, Preis et al., 2020). The variables were scaled and then mean-centered. Each model included the same set of control factors. Only cases with no missing data were included in the analysis. A probability value of $p<0.05$ indicated statistically significant results. Hosmer and Lemenshow test was used to confirm the goodness of fit for the logistic regression models. We used the percentages calculated from the obtained ORs for each variable in the models to describe the results. Analyses were performed using SPSS software, version 27 (Chicago, IL, USA).

Results

Table 1 - Descriptive statistics of the variables in the study group.

Variables		Mean	SD	Min-Max
STAI-State score		44.7	11.08	20-78
EPDS score		8.44	5.4	0-29
Life satisfaction		5.37	1.08	1-7
Socioeconomic satisfaction		4.86	1.09	1-7
Age (years)		30.7	3.87	18-43
		N	**%**	
Active smoking	Yes	209	6.2	
	No	3156	93.8	
Passive smoking	Yes	522	15.5	
	No	2843	84.5	
Difficulty falling asleep	Yes	2140	63.6	
	No	1225	36.4	
Difficulty maintaining sleep	Yes	2523	75	
	No	842	25	
Waking up too early	Yes	2137	63.5	
	No	1228	36.5	
Residence	City>100,000 residents	1688	50.2	
	City<100,000 residents	1677	49.8	
Education	Lower than tertiary	2647	78.7	
	Tertiary education	718	21.3	
Trimester of pregnancy	1	390	11.6	
	2	1268	37.7	
	3	1707	50.7	
Pregnancy complications	Yes	774	23	
	No	2591	77	
Nausea/Vomiting	Yes	2094	62.2	
	No	1271	37.8	
COVID-19 infection	Yes	445	13.2	
	No	2920	86.8	

STAI-State: State-Trait Anxiety Inventor - State [possible score: 20-80]; EPDS: The Edinburgh Postnatal Depression Scale [possible score: 0-30].

Difficulties in falling asleep and smoke exposure

Logistic regression models for both active and passive smoking were statistically significant ($p<0.001$) while controlling for confounding variables, and the Hosmer and Lemenshow test showed good model fit ($\chi^2=2.67$, df=8, $p=0.953$; $\chi^2=2.4$, df=8, $p=0.966$; respectively).

According to a logistic regression model, the results showed no evidence of a relationship between active (OR=0.98; 95% CI 0.7-1.36; p=0.882) and passive smoking (OR=1.03; 95% CI 0.83-1.284; p=0.76) and the occurrence of difficulty falling asleep (Figure 1). We found a significant

association between sleep difficulties during pregnancy and the mother's age, education level, and trimester of pregnancy, as well as the levels of anxiety and depression (Table 2).

In the study group, the chance of having difficulty falling asleep decreased by 2% with each year of maternal age. For anxiety (STAI-State) and depression (EPDS), with each one-unit increase in their values, the chance of having difficulty sleeping increased by 4%. Pregnant women with tertiary education were about 28% less likely to experience sleep problems than less educated participants. Additionally, in the third trimester of pregnancy, the chance of difficulties increased more than 2-fold compared to pregnant women in the first trimester of pregnancy (but no such difference was observed between 2nd and 1st trimester) (Table 2).

Table 2 - Odds ratios of experiencing difficulties in falling asleep according to the variables studied. Statistically significant differences are bolded.

Variables	Model 1 (active smoking)			Model 2 (passive smoking)		
	OR	95% CI	p	OR	95% CI	p
Active smoking (Yes)	0.98	0.7-1.36	0.88	-	-	-
Passive smoking (Yes)	-	-	-	1.03	0.83-1.28	0.760
Age	0.98	0.96-1	**0.04**	0.98	0.96-1	**0.043**
EPDS	1.04	1.02-1.06	**<0.001**	1.04	1.02-1.06	**<0.001**
STAI-State	1.04	1.03-1.05	**<0.001**	1.04	1.03-1.05	**<0.001**
Socioeconomic satisfaction	0.99	0.91-1.07	0.745	0.99	0.91-1.07	0.762
Life satisfaction	0.98	0.9-1.08	0.678	0.98	0.9-1.08	0.687
Pregnancy complications (Yes)	0.96	0.80-1.15	0.669	0.96	0.80-1.15	0.677
COVID-19 infection (Yes)	1.13	0.91-1.41	0.271	1.13	0.91-1.41	0.271
Residence (City>100,000)	0.91	0.78-1.06	0.215	0.91	0.78-1.06	0.217
Education (Tertiary)	0.71	0.58-0.87	**<0.001**	0.72	0.59-0.88	**0.001**
Trimester of pregnancy (1 vs. 2 trimester)	1.23	0.97-1.57	0.091	1.23	0.97-1.57	0.091
Trimester of pregnancy (1 vs. 3 trimester)	2.32	1.83-2.96	**<0.001**	2.33	1.83-2.96	**<0.001**
Nausea/Vomiting (Yes)	1.11	0.95-1.3	0.179	1.12	0.96-1.3	0.167

Early waking up and smoke exposure

Logistic regression models for both active and passive smoking were statistically significant ($p<0.001$) while controlling for confounding variables (Table 3), and the Hosmer and Lemenshow test showed good model fit ($\chi^2=10.07$, df=8, $p=0.26$; $\chi^2=5.53$, df=8, $p=0.7$ respectively).

The performed analysis showed that among women exposed to passive smoking during pregnancy, the risk of waking up too early was 29% higher (OR=1.29; 95% CI 1.04-1.6; p=0.019) compared to pregnant women not exposed to passive smoking (Figure 1). However the results indicated no evidence of an association with active smoking. For the controlled variables entering the model, there was a relationship between the place of residence, occurrence of nausea or vomiting, level of depression (EPDS), and anxiety (STAI-State) of the pregnant woman and the trimester of pregnancy and waking up too early (Table 3).

In the study group, the chance of waking up too early was 85% higher in women in the 3rd trimester of pregnancy than in pregnant women in the 1st trimester (no significant difference between 2nd and 1st trimester). The chance of experiencing sleep difficulties was also shown to be approximately 20% higher in pregnant women complaining of nausea or vomiting. In addition, for each one-unit increase in EPDS and STAI-State values, the chances of experiencing sleep difficulties was 5% and 2% greater, respectively. It was also observed that in the study group, the odds of waking up too early in a group of women living in a city with a population of more than 100,000 are 16% higher than among those living in places with less than 100,000 (Table 3).

Table 3 – Odds ratios of waking up too early according to the variables studied. Statistically significant differences are bolded.

Variables	Model 1 (active smoking)			Model 2 (passive smoking)		
	OR	95% CI	p	OR	95% CI	p
Active smoking (Yes)	1.12	0.81-1.54	0.509	-	-	-
Passive smoking (Yes)	-	-	-	1.29	1.04-1.6	**0.019**
Age	1.01	0.99-1.03	0.389	1.01	0.99-1.03	0.291
EPDS	1.05	1.03-1.07	**<0.001**	1.05	1.03-1.07	**<0.001**
STAI-State	1.02	1.01-1.03	**<0.001**	1.02	1.01-1.03	**<0.001**
Socioeconomic satisfaction	0.96	0.89-1.04	0.341	0.97	0.89-1.05	0.405
Life satisfaction	1.03	0.94-1.12	0.548	1.03	0.94-1.13	0.501
Pregnancy complications (Yes)	0.90	0.76-1.08	0.256	0.91	0.76-1.08	0.283
COVID-19 infection (Yes)	1.01	0.82-1.26	0.896	1.02	0.82-1.26	0.892
Residence (City>100,000)	1.16	1-1.34	**0.048**	1.16	1-1.34	0**.047**
Education (Tertiary)	0.87	0.72-1.05	0.143	0.89	0.73-1.07	0.208
Trimester of pregnancy (1 vs. 2 trimester)	1.15	0.91-1.46	0.237	1.15	0.91-1.46	0.237
Trimester of pregnancy (1 vs. 3 trimester)	1.85	1.47-2.34	**<0.001**	1.85	1.47-2.34	**<0.001**
Nausea/Vomiting (Yes)	1.20	1.03-1.4	**0.017**	1.21	1.04-1.41	**0.013**

Sleep maintenance issues and smoke exposure

Logistic regression models for both active and passive smoking were statistically significant ($p<0.001$) while controlling for confounding variables (Table 4), and the Hosmer and Lemenshow test showed good model fit ($\chi^2=10.53$, df=8, $p=0.230$ and $\chi^2=12.66$, df=8, $p=0.124$ respectively).

The results showed no evidence of an association between sleep maintenance issues and active or passive smoking (Figure 1). It has been shown that difficulty maintaining sleep during pregnancy is associated with various factors. These included the level of depression (EPDS) and anxiety (STAI-State), the level of socioeconomic satisfaction, the occurrence of nausea or vomiting in the pregnant woman, and the trimester of pregnancy (Table 4).

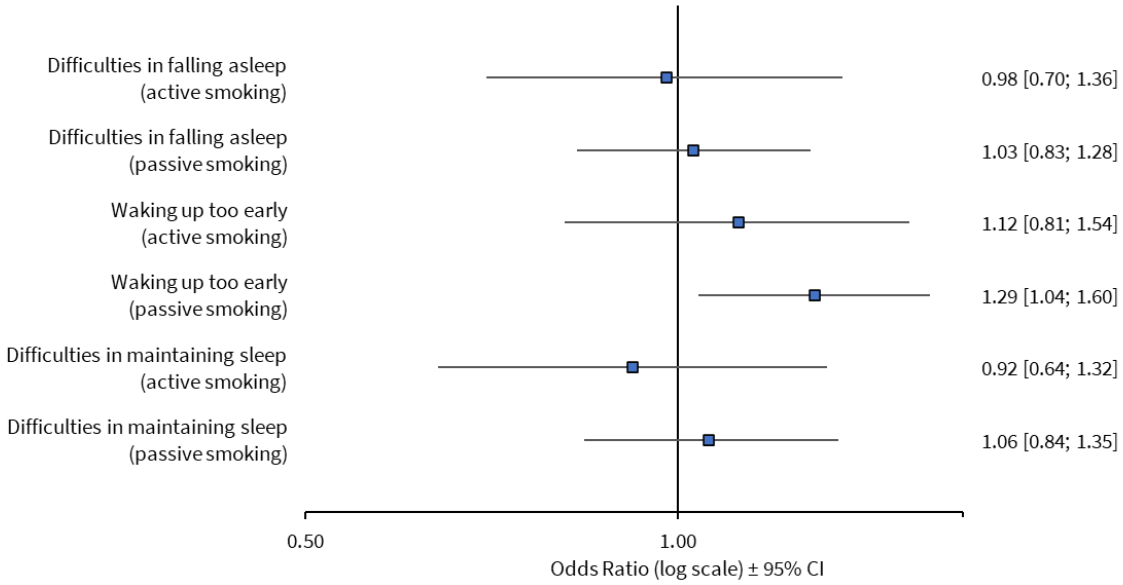

Figure 1 - Forest plot showing results of multivariate logistic regression of sleep problems. The plot shows the probability of sleep problems in pregnant women concerning active or passive smoking. Odds ratios and 95% confidence intervals (CI) from various models are shown (Table 2-4). Significant correlations are when CIs do not overlap with 1.

In the study group, if depression (EPDS) and anxiety (STAI-State) increased by 1 unit, the likelihood of experiencing sleep maintenance problems increased by 5% and 4%, respectively. On the other hand, as the socioeconomic status of an individual increases by one point, the chance of experiencing sleep maintenance issues decreases by approximately 10%. Moreover, pregnant women in the 2nd trimester of pregnancy had a 59% greater chance of experiencing sleep maintenance issues compared to pregnant women in the 1st and 3rd trimesters of pregnancy. Sleep maintenance issues were also 3.2 times higher in women in the 3rd trimester of pregnancy and 1.5 times for the 2nd trimester, relative to the first trimester. Furthermore, the chance of experiencing sleep maintenance issues was 40% higher in pregnant women complaining of nausea compared to those pregnant women not suffering from nausea or vomiting (Table 4).

Interestingly, other simulation analyses of the relationship between sleep and smoking that we conducted, such as 4 different categories of smoking in three different sleep problems and taking into account the different number of sleep disorders (1-3), showed no evidence of a relationship between smoking (passive, active) and the occurrence of sleep problems in pregnant women. The results of the analyses are available in supplementary materials (Supplementary Materials 3 and 4).

Table 4 - Odds ratios of difficulties in maintaining sleep according to the variables studied. Statistically significant differences have been bolded.

Variables	Model 1 (active smoking)			Model 2 (passive smoking)		
	OR	95% CI	p	OR	95% CI	p
Active smoking (Yes)	0.92	0.64-1.32	0.657	-	-	-
Passive smoking (Yes)	-	-		1.06	0.84-1.35	0.619
Age	1.01	0.99-1.03	0.447	1.01	0.99-1.03	0.429
EPDS	1.05	1.02-1.07	**<0.001**	1.05	1.02-1.07	**<0.001**
STAI-State	1.04	1.02-1.05	**<0.001**	1.04	1.02-1.05	**<0.001**
Socioeconomic satisfaction	0.90	0.82-0.99	0.027	0.90	0.82-0.99	**0.03**
Life satisfaction	1.09	0.99-1.21	0.085	1.09	0.99-1.21	0.082
Pregnancy complications (Yes)	0.97	0.79-1.19	0.768	0.97	0,79-1.19	0.782
COVID-19 infection (Yes)	1.07	0.84-1.37	0.574	1.07	0.84-1.37	0.575
Residence (City>100,000)	0.97	0.83-1.15	0.756	0.98	0.83-1.15	0.975
Education (Tertiary)	0.91	0.73-1.13	0.392	0.93	0.75-1.15	0.494
Trimester of pregnancy (1 vs. 2 trimester)	1.59	1.24-2.04	**<0.001**	1.59	1.24-2.04	**<0.001**
Trimester of pregnancy (1 vs. 3 trimester)	3.16	2.45-4.07	**<0.001**	3.16	2.45-4.08	**<0.001**
Nausea/Vomiting (Yes)	1.39	1.17-1.64	**<0.001**	1.39	1.18-1.65	**<0.001**

Discussion

This study aimed to examine the relationship between active smoking, exposure to cigarette smoke (passive smoking), and the prevalence of sleep problems, such as difficulty falling asleep, waking too early, and staying asleep among pregnant women. We hypothesized that active, as well as passive smoking, would increase the occurrence risk of every sleep attribute analysed in the models. We found that our hypothesis was only partially confirmed – in the study group, passive smoking was shown to increase the likelihood of prematurely interrupting pregnant women's sleep by more than 29% compared to pregnant women not exposed to passive smoking. Our results indicated that there was no evidence of an association between active or passive smoking and difficulty falling asleep or maintaining sleep. However, it is important to mention that sleep problems are not the only one aspect of health and well-being. Hence, even though we did not find a significant relationship between active smoking and sleep problems among pregnant women, it is essential to note that this does not mean that smoking is not affecting the health of women and the fetus.

Over the years, numerous scientific studies have shown a positive correlation between smoking (active and passive or only active), and sleep problems, identifying cigarette smoking as a risk factor for sleep problems (Paavonen et al., 2017; Danilov et al., 2022; Donnenfeld et al., 1993;

Wetter et al., 1994). These large studies conducted on women and/or men (Paavonen et al., 2017), rarely considered pregnant women as a study group, probably due to the small number of pregnant smokers and the general stigmatization of smoking among pregnant women (Loyal et al., 2022).

Despite the scarcity of studies on this topic, our results are consistent with those obtained by other researchers. A study of 16,000,000 pregnant Japanese women found that smoking cigarettes increased the likelihood of sleep disorders by decreasing sleep duration or sleep quality (Kaneita et al., 2005). Similar results were obtained by Danilov et al. (2022) in a study based on the Pittsburgh Sleep Quality Index questionnaire, which is used to diagnose sleep disorders. Danilov et al. also showed that pregnant smokers reported poorer sleep quality at the end of pregnancy and that sleep duration remained unchanged throughout pregnancy (Danilov et al., 2022). Similarly, in our study, we found that women in the 3rd trimester reported 2 - 3 times higher occurrence of sleep problems, than women in earlier stages of pregnancy. Our results are also consistent with the findings by Ohida et al. (2007), who reported a significant relationship between passive smoking and reduced sleep time in pregnant women (Ohida et al., 2007). Unfortunately, the previous literature on maternal passive smoking and sleeping problems is highly limited.

To consider the causes of the existing relationships between premature wakening from sleep in pregnant women and exposure to smoking, several factors should be considered, such as the probable stimulating effect of nicotine on the nervous system (Safa et al., 2020; Yang et al., 2023; O'Callaghan et al., 2019), the presence of smoking-related comorbidities (obstructive sleep apnea, bronchitis, or cough) (Chang et al., 2016), the development of pregnancy (difficulty in adopting a comfortable position, fetal movements, hormonal disturbances) (Pien & Schwab, 2004), and, above all, the environment in which the pregnant woman resides (place of residence and fellow residents). Family or friends who suffer from sleep disorders due to smoking can directly affect pregnant women's sleep (Ohida et al., 2007). It is worth noting that there may be other direct or indirect causes of too early awakening from sleep that have not been analyzed, and exposure to cigarette smoke masks them or there is a presence of an indirect factor, e.g., cigarette smoke inhalation may increase oxidative stress, leading to awakenings during the night. Due to the small number of studies on the subject, the underlying mechanisms that potentially explain sleep abnormalities in pregnant women who smoke passively have not yet been determined. To date, studies have largely focused on analyzing the relationship between sleep disorders in smoking pregnant women and the health of the baby, pointing to potential adverse changes in brain function (Kaneita et al., 2005; Shuffrey et al., 2020), or highlighting the association between the presence of anxiety disorders in a smoking mother and sleep problems in the newborn (Fakhari et al., 2012), omitting the aspect of maternal health. For this reason, further replication studies are needed to clarify the relationship between passive smoking and sleep, focusing on mother-to-be health.

Additionally, the appearance of a significant association between passive smoking and not in the case of active smoking, in the context of waking up too early can also be explained by statistical reasons - the number of women who smoke passively vs. active smokers. Pregnant women exposed to cigarette smoke were twice as many as pregnant women who smoke actively in the studied sample, which might have impacted the power of the statistical tests.

Our study indicates not only an increased risk of sleep disorders among passive smokers but also some significant effects of other independent variables considered in the models. We found that the sleep difficulties were related to age, place of residence, education, level of anxiety and depression in pregnant women, and the presence of nausea or vomiting. It is noteworthy that in all the models presented in the article, the level of anxiety, depression, and trimester of pregnancy (3rd trimester in comparison to 1st and 2nd) significantly affected the risk of occurrence of sleep problems. These results are in accordance with those of Paavonen et al. (2017), in which insufficient sleep (too little sleep) was associated with the occurrence of negative life events and depression (Paavonen et al., 2017). Similar results were obtained by Dørheim et al. (2012), based on the same method of measuring depression levels [the Edinburgh Postnatal Depression Scale (EPDS)]. This study has shown that depressive symptoms are strongly correlated with the occurrence of sleep disorders in late pregnancy, particularly with sleep length, efficiency, and difficulty of falling asleep (Dørheim et al., 2012). Importantly, pregnancy sleep problems increased

the risk of depression during pregnancy, especially in the third trimester (in comparison to depression during the first and second trimesters) (Li et al., 2023).

In all models conducted in the current study, women in the 3rd trimester had an increased risk of experiencing all measured sleep difficulties in comparison to women in 2nd and 1st trimester. A meta-analysis conducted by Sedov et al. (2018) revealed a similar significant association between the trimester of pregnancy and the prevalence of sleep disorders. The study showed that sleep quality typically deteriorates during the third trimester compared to the second (Sedov et al., 2018).

In addition, the composition of the study group is worth discussing. Our sample consisted of pregnant women of mean age 30.7, with higher education, living in cities with >100,000 inhabitants, among whom the percentage of drinkers and smokers was small. The small number of pregnant women using alcohol and cigarettes may be due to good knowledge of the negative consequences of using these substances during pregnancy and the provision of adequate support by the pregnant woman's relatives. Previously, it has been reported that mothers using addictive substances were 0.5-3 years younger and had lower education (primary or secondary) than mothers not using such substances (Nechanská et al., 2012).

It is noteworthy that the study presents 3 different sleep dysfunctions (usually, authors treat sleep problems as a single dichotomous variable, without dividing by type of problem). The differences in the results depending on the sleep dysfunction indicate that it is necessary to consider this issue in more detail than has been done so far, allowing new information to be gained about its causality, which will thus help propose more effective solutions.

Limitations

After considering the above factors, it can be concluded that our study has several limitations worth discussing. Firstly, there is a lack of a control group, and the sample is not representative – it includes female residents of large cities, with higher education and easy, with access to the Internet, so women with the highest prevalence of smoke exposure could have been less represented in our study group (Sperlich, 2014). Secondly, due to the self-reporting nature of the study, the lack of adjustment for important associated variables (e.g., physical activity, eating behavior, number of COVID-19 infections and their course), and the cross-sectional nature of the data itself, the information obtained from women may not fully describe the study group. Thirdly, it is crucial to note that the number of pregnant women who smoke or are exposed to smoking during pregnancy is likely underestimated. This is due to the continued stigmatization of the phenomenon and a sense of shame, leading many women to feel hesitant to admit to it openly. It should also be noted that our study does not involve biochemical verification of tobacco exposure, which would have helped reliably verify smoking habit use. Furthermore, the fact that many women quit smoking as soon as they discover they are pregnant or start using more discreet ways of smoking, such as nicotine patches, gum, or sachets, further limits the pool of study participants. We were also unable to determine whether pregnant women smoked cigarettes before becoming pregnant, and if so, the reason for smoking cessation. Fourthly, the structure of the questions themselves (sleep and smoking questions, author-designed and not reviewed in previous studies) may also be a limiting factor as they do not assess the number of cigarettes smoked by pregnant women, which may suggest regularity of stimulant products; therefore, occasional smoking may not be reported by survey participants. The open-ended questions about sleep used in the current study could have also been more specific and therefore accurate. The questions used in the current form do not leave much opportunity for a detailed interpretation. For example, our study lacks information about sleep duration (number of hours) and quality. Lastly, since three variables were used to verify sleep problems related to the same research question, a Bonferroni correction could have been applied. However, due to the exploratory nature and very limited previous research in this area, we did not implement this approach in the current study (Althouse, 2016).

Conclusions

To summarize, we suggest that smoking exposure during pregnancy might have a potentially detrimental impact on a mother's sleep quality, yet the limitations of the study should be taken into account when interpreting the obtained results. Given the limited number of studies on this topic, we consider our analysis to be a valuable input to the existing literature and a further cause for expanding this exploration. Future research may help emphasize the importance of health awareness programs designed to educate both the public and expectant mothers on the adverse consequences of not only active smoking during pregnancy but also passive smoking, as well as the promotion of healthy sleeping habits.

Acknowledgements

We want to thank Katarzyna Grobler-Dębska Ph.D., Waldemar Bauer Ph.D., Rafal Mularczyk, and Rebecca Brittain Ph.D. for their assistance in establishing the "Corona Mums Project" database. We also express our appreciation to all the participants who generously took part in this study. Preprint version 4 of this article has been peer-reviewed and recommended by Peer Community In Health & Movement Sciences (https://doi.org/10.24072/pci.healthmovsci.100117; Escriva-Boulley, 2025).

Funding

Our research was financed by the Priority Research Area qLife, under the "Excellence Initiative – Research University" program at Jagiellonian University in Krakow. The grant number is 06/IDUB/2019/94, awarded to U.M.M. We also received support from the Ministry of Science and Higher Education, with the grant number N43/DBS/000170, awarded to A.G.

Author contributions statement

A.A., D.P.D., A.G., M.K., U.M.M., M.M., and A.Z. conceived and designed the research. A.A., A.C., and A.G. collected the data. A.C., D.P.D., and A.G. performed statistical analysis. A.C. prepared the first draft of the manuscript. All authors have read, contributed to, and approved the final version of the paper.

Conflict of interest disclosure

The authors declare that they comply with the PCI rule of having no financial conflicts of interest in relation to the content of the article.

Data, scripts, code, and supplementary information availability

Data are available online (https://doi.org/10.5281/zenodo.15079549; Ciochoń et al., 2025). Supplementary information is available online (https://doi.org/10.5281/zenodo.14040421; Ciochoń et al., 2024).

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