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Smoke at night and sleep worse? The associations between cigarette smoking with insomnia severity and sleep duration

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ABSTRACT

Objective: Insomnia is a clinically verified nicotine withdrawal symptom. As nicotine is a stimulant, it is plausible that smoking at night could disturb sleep more than smoking at earlier times of the day, but this remains empirically unclear. This study examined smoking status and its associations with insomnia severity and sleep duration while considering the potential role of smoking time.

Methods: Data were derived from the Sleep and Healthy Activity Diet Environment and Socialization study, a community-based study of 1007 adults ($n_{\text{nonsmokers}} = 818$; $n_{\text{smokers}} = 189$) aged 22–60 from the Philadelphia area. Smoking status and time of smoking were self-reported. Insomnia was assessed with the Insomnia Severity Index and categorized as none, mild, and moderate-to-severe. Sleep duration was assessed with one item from the National Health and Nutrition Examination Survey and categorized as very short, short, normal, and long. Ordinal and multinomial logistic regressions were used to determine the association of smoking status including smoking time with insomnia severity and sleep duration controlling for sociodemographic covariates.

Results: Compared to nonsmoking, smoking was associated with experiencing increased insomnia (odds ratio = 2.5, 95% confidence interval [CI] 1.9, 3.4, $P < .001$) as well as very short (relative risk ratio = 1.9, 95% CI 1.1, 3.3) and short (relative risk ratio = 1.5, 95% CI 1.0, 2.3) sleep (vs normal sleep duration). Night-time smoking was significantly associated with greater insomnia and shorter sleep duration.

Conclusions: Findings provide evidence that smoking is associated with increased insomnia severity and shorter sleep duration, particularly nightly smoking. Sleep health should be considered in smoking cessation efforts.

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Despite the public health achievements in reducing cigarette smoking, 34.2 million (13.7%) adults continue to smoke in the United States; of those, about 3 out of 4 smoke daily.^{1,2} Cigarette smoking tends to cluster with adverse sociodemographic risk factors as well as unhealthy behaviors, such as alcohol use³ and inadequate sleep.⁴ While the comorbidity between tobacco and alcohol use has been

well documented, there is limited research investigating the association between time of cigarette smoking and poor sleep health, despite the increasing concern about the detrimental effects of inadequate sleep on health.

The public health implications of inadequate sleep and cigarette smoking

Poor sleep health is associated with a wide range of serious health consequences^{4–9}; hence, it represents a major public health concern

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and economic burden.⁵ For instance, about 30% of US adults have insomnia symptoms (eg, trouble falling and/or staying sleep).¹⁰ In 2014, population level data from the Behavioral Risk Factor Surveillance System showed that 34.8% of US adults have short sleep duration of less than 7 hours.^{10,11} Insomnia is associated with increased use of healthcare services and expenditures; for example, the direct and indirect insomnia-related healthcare costs have been estimated to be as high as \$100 billion per year.¹² The United States loses an equivalent of about 1.23 million working days annually due to insufficient sleep.¹³ Regarding cigarette smoking, it is the leading cause of preventable disease, disability, and death in the United States.^{14–16} Smoking and secondhand smoke exposure pose a heavy burden on US health and economy. Annually, almost half a million people die from smoking-related diseases in the United States.^{14,15} In fact, smoking is attributed to 32% of all cancer deaths, 87% of lung cancer deaths, and 32% of coronary heart disease deaths, among others.^{15,17} In terms of smoking-attributable annual costs, the United States spends approximately \$289 billion, including at least \$151 billion in lost productivity and \$130–\$170 billion in direct healthcare expenditures.^{15,18}

Cigarette smoking and sleep

Smoking has been associated with an array of sleep disturbances, such as changes in the basic structure of sleep (sleep architecture), insomnia symptoms, and deficits in sleep duration.⁴ More specifically, emerging research on sleep architecture has suggested that smokers spend more time in shallower, more disturbed sleep-states than nonsmokers.^{19,20} Smokers also exhibit insomnia symptoms, such as greater difficulty falling and staying asleep.⁴ Studies using polysomnography in the assessment of sleep have found that smokers have a delayed sleep time, longer sleep onset latency, and shorter sleep duration.^{4,21–23} Other cross-sectional studies have indicated that short (≤ 6 hours) and long sleepers (≥ 9 hours) are more likely to smoke than adequate sleepers.^{24–27} Consistent with objective measures of sleep duration, smokers often report increased perceptions of insufficient sleep, more daytime sleepiness, and feeling unrested or overly sleepy.^{23,28}

To better understand the relationship between smoking and sleep, it is important to consider the possible mechanisms through which tobacco smoke may affect sleep. Cigarette smoke contains many toxic, carcinogenic, and mutagenic chemicals, including nicotine, carbon monoxide, acrolein, reactive oxidant substances, among others.²⁹ Nicotine is a stimulant and creates a wide variety of biological effects on the human body including increased heart rate, blood pressure, free fatty acids, catecholamine blood levels, arousal, and alertness, among others.³⁰ Nicotine may also stimulate the release of neurotransmitters involved in regulating the sleep-wake cycle and thus, it may contribute to sleep disturbance.²⁰ Additionally, smokers may wake up more frequently during the night because of health issues related to smoking and/or nicotine withdrawal.^{20,31} Nicotine has a half-life of around 1–2 hours from the time of consumption, which means that its effects in the human body fade quickly and often lead to symptoms of withdrawal.³² Indeed, insomnia is a clinically verified nicotine withdrawal symptom.^{4,33}

Studies have also suggested that night-time smoking and/or waking up to smoke is common among smokers (19%–51%) presumably due to nicotine withdrawal.⁴ These forms of nocturnal smoking and time to first cigarette in the morning are indicative of greater nicotine dependence.^{34–36} Among the limited literature on night-time nicotine consumption and its effects on sleep, nocturnal smoking has been posited to contribute to greater sleep disturbance than non-night smoking.³¹ For example, tobacco use within 4 hours of bedtime has been associated with lower sleep efficiency and higher wake after sleep onset.³⁷ In exploratory analyses, total sleep duration has been reported to be 42.5 minutes shorter in smokers with insomnia symptoms

compared to those smokers without insomnia symptoms.³⁷ Despite these findings, there is a lack of studies investigating the connection between time of nicotine consumption and sleep outcomes.

Although there is evidence linking smoking with sleep problems, the effects of smoking on insomnia severity and sleep duration are still not well understood. It is important for tobacco and sleep research to continue growing, as the deleterious effects of smoking and poor sleep can be prevented or diminished through health behavior change. To date, very few studies have explored how time of smoking is associated with sleep. Given that nicotine is a stimulant, it is plausible that smoking at night could disturb sleep more than smoking at earlier times of the day, but this remains empirically unclear. The aim of this study was to examine smoking and its association with insomnia severity and sleep duration. We hypothesized that (1) smoking will be associated with increased insomnia severity and shorter sleep duration, and (2) the time of smoking will be related to sleep-related characteristics, such that night smokers will show greater symptoms of insomnia severity and shorter sleep duration than non-night smokers.

Methods

Participants and procedures

We used data from the Sleep and Healthy Activity Diet Environment and Socialization (SHADES) study, a community-based, nonrandom sample survey of 1007 US adults aged 22–60 designed to gain a better understanding about sleep as it relates to health, behavior, and the physical environment. The participants in the study completed a 30- to 60-minute online or in-person survey and received \$20 for their participation. The SHADES study collected data between 2012 and 2014 from 5 counties in Pennsylvania: Bucks, Chester, Delaware, Montgomery, and Philadelphia (<https://www.sleephealthresearch.com/shades/>). The Institutional Review Board of the Perelman School of Medicine approved the conduct of this investigation.

Measures

Smoking status. Self-reported current tobacco use was assessed by asking participants the question “Do you smoke cigarettes or other tobacco products?” The responses to this question were coded as “yes” or “no.”

Time of smoking. The participants who endorsed a positive response to their smoking status were asked further about the times of day they are likely to smoke. The 24-hour day was divided into the following time segments: early morning (5 AM–8 AM), morning (8 AM–11 AM), noontime (11 AM–2 PM), afternoon (2 PM–5 PM), evening (5 PM–8 PM), late evening (8 PM–11 PM), night (11 PM–2 AM), and/or late night (2 AM–5 AM). The response to each time segment was recorded in a binary fashion (“yes” or “no”) to capture whether they smoked during that time interval.

Insomnia. Insomnia was assessed using the Insomnia Severity Index (ISI),³⁸ a widely used screening tool to assess the nature, severity, and impact of insomnia over the last 2 weeks. The ISI consists of 7 items rated on a 5-point Likert scale from 0 (none) to 4 (very severe), yielding a total score ranging from 0 to 28. Total scores were categorized as follows: none (0–7), mild (8–14), or moderate-to-severe (≥ 15). For the present study internal consistency was high ($\alpha = 0.89$).

Sleep duration. Self-reported sleep duration was assessed with a single item from the National Health and Nutrition Examination Survey³⁹ “How much sleep do you usually get at night on weekdays or workdays?”. Responses were recorded as a continuous variable and classified into 4 categories: very short (≤ 4 hours), short (5–6 hours), normal (7–8 hours), and long (≥ 9 hours) based on previous studies.⁴⁰

Covariates. In line with previous research examining social determinants of smoking and/or sleep,^{41–44} sociodemographic covariates included age, sex (male, female), education (less than 9th grade, 9th–11th grade, high school or GED, some college, associate's degree, bachelor's degree, master's degree, or doctoral degree), and race/ethnicity (non-Hispanic White, Black, Hispanic/Latino, Asian, American Indian/Native American, or Alaskan Native). Body mass index (BMI), calculated by the ratio of self-reported weight and squared height (kg/m^2), was also included as a covariate based on previous sleep research.^{28,45}

Statistical analyses

Descriptive statistics were calculated for all variables. Sample characteristics were compared across smoking status using chi-square tests for categorical variables and *t* tests for continuous variables. To determine whether smoking status was associated with sleep duration and insomnia severity, insomnia severity and sleep duration were entered as outcome variables in separate regression models with smoking status (yes or no) as predictor variable. For sleep duration, multinomial logistic regressions were used, with normal sleep (7–8 hours) considered the reference group, compared with very short, short, or long sleep duration. In models where insomnia severity was the outcome, the outcome was considered as ordinal, with no insomnia vs mild and moderate-to-severe insomnia. Unadjusted models were computed, as well as models adjusted for age, sex, education, race/ethnicity, and BMI. To determine whether likelihood of smoking at a particular time was associated with sleep duration or insomnia severity, similar models were computed, with smoking at each time segment (yes or no) included as the predictor, rather than smoking status. All statistical analyses were conducted in STATA 14.0 (STACORP, College Station, TX).

Results

Sample characteristics

Characteristics of the sample are reported in Table 1. Among all study participants, 39% were male, 56% were college graduates, and 60% were non-Hispanic White; the mean age was 34 years (standard deviation = 9.4). When smokers and nonsmokers were compared, smokers were nominally older, more likely to be male, less likely to be college educated, more likely to be Black/African-American, more likely to have a higher BMI, and were more likely to report shorter sleep or insomnia. Among smokers, the prevalence of smoking at various clock times was as follows: 58.2% (5 AM–8 AM), 77.8% (8 AM–11 AM), 76.7% (11 AM–2 PM), 74.6% (2 PM–5 PM), 83.6% (5 PM–8 PM), 79.4% (8 PM–11 PM), 59.8% (11 PM–2 AM), and 35.5% (2 AM–5 AM).

Smoking status, insomnia severity, and sleep duration

In ordinal logistic regression analysis, smoking was associated with increasing insomnia severity categorized as: none, mild, and moderate-to-severe insomnia (odds ratio = 2.5, 95% confidence interval [CI] 1.9, 3.4, $P < .001$). More specifically, for smokers, the odds of experiencing moderate to-severe insomnia (vs the combined categories of mild and no insomnia) were 2.5 times higher than for nonsmokers. Likewise, the odds of the experiencing moderate-to-severe and mild insomnia (vs no insomnia) were 2.5 times higher for smokers compared to nonsmokers. The relationship between smoking and insomnia severity remained significant after adjusting for the covariates age, sex, education, race/ethnicity, and BMI (odds ratio_{adjusted} = 1.9, 95% CI 1.4, 2.7, $P < .001$), suggesting that the odds of smokers experiencing greater insomnia severity (vs a lower insomnia severity category) were 1.9 times as large as those for nonsmokers.

Table 2 presents the results from the multinomial logistic regression models examining smoking status and its association with sleep duration. Smoking was associated with 3.3-fold (95% CI 2.0, 5.5) higher odds of experiencing very short sleep (vs normal sleep) and with 1.9 (95% CI 1.3, 2.7) higher odds of experiencing short sleep (vs normal sleep) compared to nonsmoking. After adjusting for covariates, the strength of the associations between smoking and very short and short sleep duration decreased but remained significant (Table 2). No significant associations were found for smoking status and long sleep duration.

Smoking time associated with insomnia severity and sleep duration

Table 3 shows the relationship between time of smoking and insomnia severity using ordinal logistic regression models. When compared to non-night smoking, smoking at night (11 PM–2 AM) was associated with 2.4-fold (95% CI 1.4, 4.1) increased odds of experiencing insomnia at a higher severity level (vs a lower insomnia severity category) in the unadjusted model; this relationship remained significant after adjusting for covariates (odds ratio_{adjusted} = 2.7, 95% CI 1.5, 4.9). Similarly, smoking in the late night (2 AM–5 AM) was associated with 2.5-fold (95% CI 1.4, 4.5) higher odds of greater insomnia severity (vs a lower insomnia severity category) in the unadjusted model, and with 2.9-fold (95% CI 1.6, 5.5) increased odds after adjusting for covariates.

In terms of sleep duration, smoking at night (11 PM–2 AM) was associated with a greater likelihood of having short sleep vs normal sleep (relative risk ratio = 2.3, 95% CI 1.1, 4.7, $P = .024$). No other significant associations were found for any sleep duration category as an outcome. Additionally, post hoc analyses were conducted to explore whether the relationship between smoking at night and short sleep duration was accounted by insomnia. Results showed that the relationship between smoking and short sleep duration was nonsignificant in models that included insomnia severity.

Discussion

Cigarette smoking and sleep problems are common in the general population and represent serious public health problems. This study provides deeper understanding into cigarette smoking and its association with insomnia severity and sleep duration by highlighting the importance of time of smoking. Consistent with our study hypotheses, smoking was associated with higher odds of experiencing increased levels of insomnia severity in unadjusted and adjusted models for age, sex, education, race/ethnicity, and BMI. We also found that smoking was related to short (≤ 4 hours) and very short (5–6 hours) sleep duration even after adjustment for sociodemographic covariates. These findings are congruent with prior research implicating a connection between smoking and sleep disturbances.⁴ Notably, few studies have examined smoking status with a focus on insomnia severity as this study did. Our study is an important step forward in providing valuable empirical information about time of smoking in relation to insomnia severity and short sleep duration. Findings may help guide new research directions and clinical treatment, especially when considering that there is increasing interest in targeting sleep among tobacco users as a promising adjunctive therapy to promote smoking cessation and relapse prevention.^{46,47}

Moreover, as hypothesized, the present study found that nocturnal smoking was particularly associated with increased odds of greater insomnia severity and short sleep duration.

Our findings align with Peters et al's cross-sectional study³¹ that found that night smokers reported more sleep disturbance than non-night smokers, including increased sleep latency and decreased sleep duration as assessed by the Pittsburgh Sleep Quality Index. It is plausible that the stimulant effects of nicotine may help explain the

Table 1
Sample characteristics

Variable	Category or units	Full sample N = 1007	Nonsmokers n = 818	Smokers n = 189	P
Age	Years	34.0 ± 9.4	33.2 ± 9.1	37.4 ± 10.0	<.0001
Sex	Male	38.53%	35.09%	53.44%	<.0001
	Female	61.47%	64.91%	46.56%	
Education	College	55.91%	62.96%	25.40%	<.0001
	Some college	30.98%	28.97%	39.68%	
	High school	10.53%	6.97%	25.93%	
	Less than high school	2.58%	1.10%	8.99%	
Race/ethnicity	Non-Hispanic White	59.52%	59.88%	57.98%	.0119
	Black/African-American	25.02%	23.19%	32.98%	
	Hispanic/Latino	4.59%	4.79%	3.72%	
	Asian	5.48%	6.13%	2.66%	
	Other/multiracial	5.38%	6.01%	2.66%	
Body mass index	kg/m ²	26.6 ± 6.5	26.5 ± 6.6	27.1 ± 6.4	0.2608
Sleep duration	Normal	47.67%	50.73%	34.39%	<.0001
	Very short	9.53%	7.70%	17.46%	
	Short	37.84%	36.06%	45.50%	
	Long	4.97%	5.50%	2.65%	
Insomnia severity	None	34.76%	38.75%	17.46%	<.0001
	Mild	38.63%	38.02%	41.27%	
	Moderate-to-severe	26.61%	23.23%	41.27%	

Table 2
Multinomial logistic regression models examining smoking status (nonsmoking as reference) and its association with sleep duration

Outcome	Unadjusted		P	Adjusted*		P
	RRR	95% CI		RRR	95% CI	
Very short sleep vs normal sleep	3.344	(2.037, 5.49)	<.001	1.877	(1.056, 3.338)	.032
Short sleep vs normal sleep	1.861	(1.305, 2.655)	.001	1.540	(1.04, 2.283)	.031
Long sleep vs normal sleep	0.709	(0.272, 1.853)	.483	0.978	(0.357, 2.681)	.966

RRR, relative risk ratio; CI, confidence interval.

* Model adjusted for age, sex, education, race/ethnicity, and body mass index. For all models, sleep duration was the outcome variable, and smoking status was the predictor variable.

Table 3
Results of the ordinal logistic regression models regarding the relationship between time of smoking and insomnia severity

Time of smoking	Insomnia severity		Adjusted*	
	Unadjusted OR	95% CI	OR	95% CI
Early morning 5 AM-8 AM	1.077	(0.626, 1.856)	0.972	(0.546, 1.732)
Morning 8 AM-11 AM	0.742	(0.383, 1.440)	0.847	(0.404, 1.777)
Noontime 11 AM-2 PM	1.536	(0.821, 2.873)	1.488	(0.741, 2.986)
Afternoon 2 PM-5 PM	1.021	(0.551, 1.890)	0.995	(0.501, 1.977)
Evening 5 PM-8 PM	1.145	(0.557, 2.358)	1.478	(0.635, 3.439)
Late evening 8 PM-11 PM	1.022	(0.528, 1.978)	1.167	(0.555, 2.452)
Night 11 PM-2 AM	2.359**	(1.350, 4.122)	2.695**	(1.481, 4.903)
Late night 2 AM-5 AM	2.525**	(1.414, 4.508)	2.932**	(1.550, 5.546)

OR, odds ratio; CI, confidence interval.

* Model adjusted for age, sex, education, race/ethnicity, and body mass index.

** $P < .01$. For all models, insomnia severity functioned as the outcome variable and time of smoking as the predictor variable.

detrimental role of nocturnal smoking on sleep outcomes. Previous research has suggested that transdermal nicotine administration before or during sleep increases sleep latency and reduces sleep duration, including rapid eye movement sleep duration.^{48,49} A more recent study conducted in mice found that oral nicotine administration and abstinence lead to sleep disturbances, such as sleep fragmentation, decreased sleep duration, and changes to rapid eye movement sleep.⁵⁰ In humans, Spadola et al³⁷ found that smoking within 4 hours of bedtime was associated with increased sleep fragmentation.

Interestingly, our study results further revealed that the relationship between night smoking and short sleep was fully explained by underlying symptoms of insomnia, as measured by the ISI. In line with prior work³⁷ suggesting that smokers with sleep problems (eg, insomnia symptoms) may be particularly sensitive to nightly nicotine use, our finding calls attention to the importance of addressing insomnia as a potential robust mechanism for improving other sleep deficits among night smokers, such as reduced sleep duration. It is noteworthy that additional studies with larger sample sizes are needed to substantiate current findings and to shed further light on the association between night smoking and sleep. Future research could examine factors leading to night smoking behaviors and test potential interactions between time of last cigarette smoked prior to bedtime, nicotine dependence, and sleep disturbance.

While the current study examined smoking as it relates to insomnia severity and sleep duration, it is important to note that we cannot rule out the possibility of reverse directionality. For instance, Patterson et al²⁵ found that short sleepers had greater odds of being smokers than adequate sleepers. They also reported that sleep chronotype (ie, the degree to which an individual prefers morning or evening) was linked to smoking status, with those reporting a later sleep timing more likely to be smokers. Similarly, Patterson et al²⁶ used repeated assessment data from the UK Biobank study and found that worsening sleep duration predicted increased cigarette consumption. Taken current and previous findings together, it is evident that the relationships between smoking and sleep disturbances (eg, insomnia and sleep duration, among others) are complex. Additional research is warranted to address the directionality of smoking and sleep

outcomes, as well as the role of cigarette use timing, with the intention to better inform clinical interventions targeting these behaviors.

There are some limitations that need to be considered when interpreting study results. For example, our cross-sectional study design impedes establishing temporal and causal relationships between smoking and insomnia severity and sleep duration. Also, this study relied on a nonrandom sample of individuals limiting its external validity as well as on self-report measures, which could have introduced bias from participants' recall inaccuracies or social desirability. Another limitation is that there are more factors besides the multiple sociodemographic covariates included in this study that could influence smoking behavior and sleep outcomes, and that our choices in terms of which covariates to include were limited to those that had been used in previous literature. Future studies could more deeply confirm the inclusion of these covariates and other covariates (eg, health comorbidities, alcohol use, and caffeine consumption) that may confound or moderate the relationship under study here using causal graphs. Lastly, the current study measured smoking status based on a single item regarding tobacco use and did not collect data on amount of nicotine consumption or dependence (eg, the number of cigarettes smoked per day or pack-years, or their serum or salivary cotinine levels) and on form of nicotine intake (eg, traditional cigarettes, electronic cigarettes [e-cigarettes], and vapes); therefore, results should be interpreted within the context of study limitations. Future research could use actigraphy in conjunction with self-report measures (eg, sleep diaries and/or questionnaires) to comprehensively examine how the amount, pattern, and form of nicotine consumption at specific times of day (eg, nocturnal nicotine intake) relates to sleep disturbance. Studies assessing the use of various e-cigarettes types with and without concurrent use of traditional tobacco cigarettes among different populations are warranted, given the increased use of e-cigarettes in recent years⁵¹ and the potential for e-cigarette use to negatively impact sleep, as found in a study among college students.⁵²

Despite these limitations, this study has notable strengths. Our study contributes to research efforts aimed at reducing current gaps in sleep health among cigarette smokers by providing further scientific support that smoking is associated with higher levels of insomnia severity and shorter sleep duration, and by highlighting the detrimental role of nightly smoking on these relationships. The important implications of our findings should be considered in the broader context of sleep health among smokers and smoking cessation efforts. For example, clinicians and researchers should consider how smoking status and time of smoking may impact sleep, which is of significance given that night smokers are at increased risk for unsuccessful smoking cessation attempts compared to non-night smokers.^{34,35} Furthering knowledge about modifiable behaviors (eg, time or amount of nicotine intake) relevant to sleep health may be useful when working with smokers struggling with complete smoking cessation; a fruitful future direction may be testing clinical interventions recommending smoking avoidance at night to improve sleep. It is important for professionals to be aware of the multiple factors impacting both smoking and sleep behaviors to better assist and promote health behavior change. Smokers should be provided with information about the relation between cigarette smoking and sleep disturbances (eg, increased insomnia and reduced sleep duration). Future research should continue to examine the association between smoking status, insomnia severity, and sleep duration, as understanding these connections may be essential for promoting effective smoking cessation and better sleep health.

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