The relationship between poor sleep quality measured by Pittsburgh Sleep Quality Index and
cigarette smoking according to sex and age

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ABSTRACT

OBJECTIVES: Several reports have described that cigarette smokers are more likely to experience sleep disturbances. This study aimed to evaluate the differential associations between smoking and sleep quality according to sex and age group, which were not adequately characterized in previous studies.

METHODS: Data analysis was conducted with a nationally representative sample of 224,986 Korean adults collected from the 2018 Community Health Survey. Sleep quality, as the dependent variable, was measured with the Pittsburgh Sleep Quality Index (PSQI), with the PSQI score dichotomized as good (≤ 4) or poor (> 5). Multiple logistic regression analysis was performed considering socio-demographic factors, health behaviors, comorbidities, and psychological factors as covariates.

RESULTS: The overall weighted prevalence of poor sleep quality was 39.4% (95% CI: 39.1~39.7%). In the multivariate model excluding psychological factors, poor sleep quality was positively correlated with smoking in both sexes and in all age groups except in males aged ≥ 65 years. However, in the full model including psychological factors, statistically significant odds ratios of poor sleep quality according to smoking level were observed only in women under 65 years of age, and the values were around 1.5.

CONCLUSION: The relationship between poor sleep quality and cigarette smoking differs according to sex and age group. Smoking cessation interventions to improve sleep quality need to be preferentially applied to women, especially those under middle age, in addition to solutions for psychological problems.

Key words: Sleep quality, Pittsburgh Sleep Quality Index, Smoking behavior, Sex, Age group

INTRODUCTION

Despite the lack of definitive consensus in the field of sleep medicine, the term “sleep quality” has been widely used as a collection of sleep measures (total sleep time, sleep onset latency, sleep fragmentation, total waketime, sleep efficiency, and sleep disruptive events such as apnea), these factors are closely related with sleep disorders [1]. The number of people experiencing sleep disorders has been recently increasing in several countries. In 2017, about a third of adults in the U.S. reported short sleep of 6 or fewer hours a day, an increase of 15% since 2004 [2]. According to a review article on Australian sleeping habits, frequent (daily or almost daily) sleep disturbances (starting and maintaining sleep, experiencing inadequate sleep), daytime fatigue, drowsiness, and irritability were very prevalent, with their incidences ranging from 20% to 35% [3]. In a 2012 survey conducted in the Netherlands, 32.1% of the respondents reported general sleep disorders, 43.2% reported a lack of sleep, 8.2% experienced insomnia, 5.3% showed circadian rhythm sleep disorders, 6.1% had parasomnia, 5.9% reported hypersomnolence, 12.5% experienced restless leg disorder and limb movement during sleep, 7.1% showed sleep-related breathing disorder, and 12.2% reported two or more comorbidities [4].

Several studies have identified smoking as one of the important factors related to sleep disorders. Smokers were 1.47 times more likely to experience sleep-related issues than non-smokers in a meta-analysis [5]. In a study of young adults, poor sleep quality measured with the Pittsburgh Sleep Quality Index (PSQI) was associated with higher cigarette consumption, more frequent withdrawal symptoms, more frequent cravings, higher modified Fagerstrom Tolerance Questionnaire scores, and more ICD-10 criteria for tobacco dependence [6, 7]. In a study conducted in Indonesia, current smokers were 1.39 times and heavy smokers were 1.91 times more likely to face sleep disturbance, measured by ten validated indicators of

sleep quality and sleep deprivation than nonsmokers [8]. Moreover, smokers with obstructive sleep apnea diagnosed on the basis of polysomnography showed a higher apnea-hypopnea index measured by diagnostic criteria, lower mean oxygenation during sleep, and more daytime sleepiness [9].

The low sleep continuity and sleep efficiency in smokers may be partly explained by the effects of nicotine dependence [10]. Due to differences in nicotine metabolism by age and sex, and the changes in sleep habits with age, the effect of smoking on sleep may also differ according to sex and age [10, 11]. A few studies have shown the differential association between smoking and sleep disturbance according to sex or age. Among Hispanic/Latino Americans aged 18-76 years, younger female smokers aged 35-54 years were 1.83 times more likely to experience sleep-disordered breathing (SDB) and the use of 10 cigarettes or more per day was associated with a 2.72-fold increase in the odds for SDB in comparison with younger female never smokers. These associations were not observed in male participants and female participants of other age groups [12]. Stronger associations were observed among females in a Canadian nationwide study, where elevated urinary cotinine concentrations were associated with significantly higher odds of short or long sleep duration, trouble falling or staying asleep, sleep dissatisfaction, and increased number of sleep problems [13]. In a study on Japanese workers, the odds of difficulty awakening in the morning in current smokers were significantly higher for women and men compared to those for never smokers, while increased difficulty initiating sleep and decreased early morning awakening were found only in women [14]. However, a study in American adults showed no significant interaction between sex and smoking for self-reported snoring, short sleep, or poor sleep [15].

To prevent or manage sleep disorders related to smoking, a differential approach

strategy based on sex and age is essential. However, studies on this aspect are lacking, and, to the knowledge of the authors, studies on the relationship between smoking and sleep quality that consider both sex and age simultaneously are rare. The purpose of this paper is to investigate the differential relationship between smoking and sleep quality measured by PSQI in relation to sex and age in adults by using Korean national representative data.

MATERIALS AND METHODS

Study population

This study used the 2018 Korea Community Health Survey (KCHS) data recorded by the Korea Centers for Disease Control and Prevention to investigate community health and health-related behaviors. KCHS is conducted in 255 municipalities containing community health centers. Participating households were selected using stratified cluster sampling methods; all household members aged ≥ 19 years were included. Approximately 900 people per municipality participated in the survey. Qualified interviewers visited the sampled houses and collected data via face-to face interviews. Detailed information about the KCHS is available elsewhere [16].

Of the 228,340 participants, the present study used data of 224,986 participants, excluding 3,354 participants (1.5% of all participants) who provided incomplete responses for all variables (including PSQI, smoking behavior and psychological factors) considered in this study.

Measures

Sleep quality

Sleep quality was measured using the Korean version of the PSQI questionnaire, which has

been widely used for evaluating sleep quality [17, 18]. The PSQI consists of 7 sleep components covering 19 items over the past 1 month: 1) subjective sleep quality, 2) sleep latency, 3) sleep duration, 4) sleep efficiency, 5) sleep disturbances, 6) use of sleep medication, and 7) daytime dysfunction. Each component is scored from 0 to 3 points, and the PSQI score is calculated as the sum (ranged from 0 to 21) of the 7 components. A PSQI score of >5 was defined as indicating poor sleep quality.

Smoking behavior

Smoking behavior was classified into three categories based on the amounts and frequency of cigarette use: 1) non-smokers, 2) occasional smokers or daily smokers (<1 pack per day), 3) heavy daily smokers (≥ 1 pack per day). The proportion of occasional smokers was very low (overall: 1.2%; 2.3% in males and 0.5% in females), so they were grouped together with the daily smokers (<1 pack per day). People who had never used cigarettes, who had smoked less than 100 cigarettes in their lifetime, or who had smoked ≥ 100 cigarettes in their lifetime but quit were classified as non-smokers. The second and third groups corresponding to current smokers were defined as those who smoked more than 100 cigarettes in their lifetime and currently smoked. Among current smokers, those who smoked non-daily (occasional smokers) or smoked less than 1 pack per day were defined as the second group. The third group was defined as those who smoked more than one pack per day.

Other covariates

The sociodemographic characteristics of the study participants were sex (male, female), age (19-35, 36-64, ≥ 65 years, classified based on the American Psychological Association) [19], educational level ($\leq$ high school, $\geq$ college), and employment (yes, no). Health behavior related factors were alcohol consumption within 1 year (non-drinker, ≤ 1 per month, 2-4 per month, 2-3 per week, ≥ 4 per week) and walking exercise (< 4 per week, ≥ 5 per

week). Physician diagnosis experience of hypertension or diabetes were considered as a comorbid factors.

The psychological factors, including perceived stress level, depressive mood, and subjective health status, were also included due to their probable association with sleep quality. Perceived stress level was classified into four groups (little, low, high, very high) using the following questions (“In general, how stressed do you feel in everyday life?”). Depressive mood was defined as yes or no using the following questions (“In the past 1 year, have you felt sadness or despair to the extent that you could not complete everyday activities for 2 consecutive weeks or more?”). Subjective health status was categorized into three groups (high, middle, low).

Statistical analysis

The weighted percentages of poor sleep quality (PSQI > 5) were calculated in relation to various characteristics. The relationship between sleep quality and smoking was stratified by sex because of the large difference in smoking prevalence between men and women in Korea. Logistic regression was used to evaluate the factors associated with sleep quality. Considering the strong effect of psychological factors on sleep quality, the results of two models (two types of adjusted odds ratios [ORs]) were presented depending on whether these factors were included. Because of the differences in the metabolic processes of nicotine and cotinine or in the relationship between sleep quality and tobacco smoking according to sex and age [10, 13, 20], we performed separate analyses stratified by sex and age group to explore the potential effects on the association between cigarette smoking and sleep quality. An interaction model was used to estimate the effect of smoking on sleep quality according to age group.

All analyses were performed using the SPSS version 19.0 (IBM, Armonk, NY, USA). A p-value < 0.05 indicated statistical significance. Complex SPSS sampling methods were used to accurately represent the Korean adult population.

Ethics statement

The KCHS data did not include personal information, and participants responded anonymously. The raw data of KCHS are available publicly and were exempted from the institutional review board review by the Korea Centers for Disease Control and Prevention.

RESULTS

The characteristics of the study participants and the level of poor sleep quality associated with each characteristic are shown in Table 1. Of all the study participants, 39.4% had poor sleep quality. The sleep quality was lower in females, elderly participants, those with a low education level, no employment, or less walking exercise, and those who were diagnosed with hypertension or diabetes. In particular, the difference in sleep quality for psychological factors was meaningfully large (gap between the maximum and the minimum $> 20\%$) for each factor. On the other hand, sleep quality showed no consistent dose-response relationship with the level of smoking or drinking when the results were not stratified by sex (Table 1).

Table 2 illustrates the factors related to poor sleep quality after stratification by sex. The crude ORs for poor sleep quality compared to non-smokers was 1.09 (95% confidence interval [CI] 1.05–1.14) for occasional and daily smokers (<1 pack per day) and 1.30 (95% CI 1.24–1.36) for daily smokers (≥ 1 pack per day) in men, and 1.96 (95% CI 1.80–2.15) for occasional and daily smokers (<1 pack per day) and 2.45 (95% CI 1.97–3.04) for daily smokers (≥ 1 pack per day) in women. In the multivariate model excluding psychological

factors, sleep quality and smoking showed a significant dose-response relationship as in the univariate model. In the model that was additionally adjusted for psychological factors, the strength of the relationship between smoking and sleep quality was weaker than that in the previous model, and the dose-response relationship disappeared, but significant results were still observed in women (adjusted OR = 1.50, 95% CI 1.36–1.65 for occasional & daily smokers [<1 pack per day], adjusted OR=1.45, 95% CI 1.16–1.81 for daily smokers [≥ 1 pack per day]). Among men, only those who smoked more than 1 pack per day showed significantly lower sleep quality, with a decreased adjusted OR value of 1.08 (95% CI 1.02–1.14). In this fully adjusted model, all variables except comorbidities were correlated with poor sleep quality in both sexes, and the adjusted OR of psychological factors was the largest (Table 2).

In each group classified by sex and age group, the adjusted ORs without adjustment of psychological factors for poor sleep quality increased with higher smoking frequency/amount in both men and women aged 19-35 years, and the strength of this association was smaller in the elder group (aged 36-64 years) and in men in comparison to those in the younger group (aged 19-35 years) and in women, respectively. After additional adjustment for psychological factors, significant association between smoking and sleep quality was maintained in women aged 19-35 years (adjusted OR = 1.49, 95% CI 1.24–1.79 for occasional & daily smokers [<1 pack per day]) and 36-64 years (adjusted OR = 1.56, 95% CI 1.37–1.77 for occasional & daily smokers [<1 pack per day], adjusted OR = 1.49, 95% CI 1.14–1.95 for daily smokers [≥ 1 pack per day]), but the dose-response relationship according to smoking level disappeared, and the significance also disappeared in men and women over 65 years of age (Table 3). Similarly, as a results of the analysis by age 10 year group, the relationship between smoking and sleep quality in final model was not clearly observed in men, but

showed a significant association in women under 70 years of age (Supplementary Material 1). In addition, even after classifying non-smokers into never-smokers and past smokers, a significant association was observed in under 65 years of age, and a significant association was also seen in men, but the strength of the association was lower than that of women (Supplementary Material 2).

The results from the interaction model are shown in Figure 1. In men, a significant association between smoking and poor sleep quality was only found under the age of 35, indicating that there was a significant interaction between age group and smoking (P for interaction=0.020). On the contrary, in women, smoking tended to affect the sleep quality regardless of age group, so there was no interaction effect between the two factors (P for interaction=0.232)(Figure 1).

DISCUSSION

The overall weighted prevalence of poor sleep quality according to PSQI > 5 in this study was 39.4% (95% CI: 39.1~39.7%), which was similar to the prevalence of 36% reported in the German general population [21] and much higher than the 26.6% prevalence reported in China [22]. This high prevalence of poor sleep quality highlighted the need for further research to elucidate the causes and related factors for sleep disorders.

In this study, there was a significant relationship between poor sleep quality and smoking only in women under the age of 65, and no significant results were found in men and older women. In other words, the relationship between smoking and sleep quality was different according to sex and age group, this was also supported by the interaction model. These results can be derived from the application of various modelling methods. When the results were not adjusted for confounding variables, statistically significant correlations

between poor sleep quality and cigarette smoking level as well as dose-response relationships were observed in both sexes. Even after adjustment for socioeconomic factors such as age, education level, and employment status; health behaviors such as alcohol consumption and walking exercise; and comorbidities such as hypertension and diabetes, these correlations showed a similar pattern. These results are consistent with the findings from previous studies that observed associations between smoking and sleep quality measured by PSQI in a general population [23-25]. All confounders mentioned above were significantly associated with poor sleep quality in this study. Nevertheless, the adjusted odds ratios remained almost unchanged in comparison with the crude odds ratios, which suggests that smoking was associated with sleep independent of these factors. However, when stratified by age group, a distinct dose-response relationship between poor sleep quality and cigarette smoking level was observed only in the participants aged 19-35 years. When the psychological factors, including perceived stress level, depressive mood, and subjective health level were adjusted additionally, the odds ratios of poor sleep quality decreased generally, and statistically significant odds ratios of poor sleep quality according to smoking level were observed only in women aged under 65 years. Previous studies that showed a significant relationship between smoking and sleep quality did not include elderly participants [23] or included only a small proportion of elderly participants [24], and did not present results by age group [23, 25]. Moreover, some of these studies did not consider psychological factors in the statistical model [32, 33]. This study attempted a different approach to reveal the relationship between smoking and sleep quality by adjusting for various potential confounders, including psychological factors, and by considering the interaction between sex and age group, which was not considered in previous studies.

The mechanism by which cigarette smoking causes sleep disturbances has been studied

by several researchers. Nicotine, the major pharmacologically active compound in tobacco, affects the central nervous system by stimulating the nicotine-acetylcholine receptor. The activation of nicotinic receptors leads to the release of several neurotransmitters, including acetylcholine, dopamine, serotonin, norepinephrine, and gamma-aminobutyric acid (GABA). The deleterious effects of nicotine on sleep quality may be attributable to the independent and interactive effects of these neurotransmitters on the central mechanisms regulating the sleep-wake cycle, resulting in increased sleep latency and contributing to sleep disturbance [26-28]. In addition to the direct action of nicotine on the sleep mechanism, smokers may experience withdrawal symptoms and cravings due to a reduction in nicotine levels after sleep because the half-life of nicotine in the human body is only 1-2 hours. This may reduce the quality of sleep in smokers [8, 29]. Medical conditions and lifestyle habits related to smoking may lead to a decrease in the quality of sleep. In comparison with nonsmokers, smokers are more likely to have mental problems such as stress and depression as well as diseases such as cardiovascular disease, respiratory diseases including obstructive lung disease, diabetes, and obesity. They also tended to consume more alcohol and caffeine [8, 28, 30, 31].

Poor sleep is known to be associated with poor health-related quality of life and symptoms of depression and anxiety, all of which are associated with current cigarette smoking [8]. Mental problems, such as depression, stress, and anxiety, have been consistently suggested to be strongly related to smoking in most studies, although the causal relationships are inconsistent. Self-rated health has also been reported to be associated with smoking [32-34]. In this study, the perceived stress level, depressive mood, and subjective health level showed distinct dose-response relationships or statistically significant independent relationships with poor sleep quality in individuals of both sexes. Thus, these

variables showed a greater correlation with poor sleep quality than smoking when the correlation between smoking and poor sleep quality reduced or the statistical significance disappeared after adjusting for them. However, since the direction of the relationship between these variables and smoking is unclear, the potential effect of smoking on poor sleep quality should not be underestimated.

When stratified by sex and age group, the odds ratios (crude OR and adjusted OR except for psychological factors) of poor sleep quality according to smoking level tended to be smaller as the age group increased in both sexes. This was presumed to be partly due to differences in nicotine metabolism according to age. In a study with healthy elderly and adult participants, compared to adults aged 22~43 years, elderly individuals aged 65-76 years showed significantly lower total nicotine clearance (-23%), nonrenal clearance (-21%), and renal clearance (-49%). The maximal heart rate response to nicotine was also reduced in elderly participants (-29%). This decreased nicotine clearance may delay or alleviate withdrawal symptoms or cravings during sleep [20]. In addition, the decrease in the relationship between smoking and sleep quality with age can also be explained by the natural changes in sleep patterns as a part of the normal ageing process, which may reduce the relative effects of smoking on sleep quality [35]. One study showed a significantly longer wake time after sleep onset, reduction in total sleep time and sleep efficiency, and higher arousal index, which were measured by polysomnography, among older men and women after adjusting for race, use of hormone replacement therapy, smoking history, sleep apnea, and chronic health conditions [36]. The disappearance of the dose-response relationship between poor sleep quality and smoking level in individuals older than 35 years is also presumed to be due to the relative decrease in the effect of smoking on sleep quality with age. However, further research is needed to explain these findings.

Another noteworthy point in this study was that the odds ratios of poor sleep quality related to cigarette smoking level in women were greater than those in men in all age groups. Sex differences in the sensitivity and metabolization rate of nicotine can explain the stronger association between tobacco smoke exposure and poorer sleep quality among females [13]. In one study of twins, the clearances of nicotine and cotinine, the nicotine-to-cotinine clearance ratio, and the trans-3'-hydroxycotinine/cotinine ratio were significantly higher in women than in men. However, the findings for menopausal or postmenopausal women were not different from those for men. Thus, accelerated nicotine metabolism appears to be influenced by sex hormones, specifically estrogen [37]. In addition, menopause is a strong risk factor for SDB, and male sex alone increases the risk of SDB 2-3 times. Therefore, the effects of smoking may be less powerful in menopausal women and men [12]. This could partly explain why the odds ratios among women aged 65 years or older were lower than those in younger groups of women, along with the other ageing effects mentioned above.

This study had a few limitations. First, the causal relationship of smoking behaviors and sleep quality could not be determined, which is an inherent limitation of a cross-sectional survey. Second, occasional smokers and daily smokers who smoked less than 1 pack per day were not subdivided into separate groups because of the very small number of occasional smokers. Third, the failure to account for confounders known to affect sleep quality, such as obesity and respiratory disease, may have also influenced the results [38]. Although its results were not presented, an analysis including obesity was also attempted in this study. However, since height and weight information were omitted in more than 20% of cases and obesity was not related to sleep quality, these data were excluded from the final analysis. Fourth, past smokers were not separated from non-smokers in the main analysis. However, the mechanism of poor sleep quality in smokers may be explained by nicotine metabolism or

withdrawal symptoms in current smokers. Therefore, non-smokers and past smokers can be classified into the same group as they will not be significantly affected differently by nicotine metabolism. In a complementary manner, the results of analysis of non-smokers into past smokers and never-smokers are presented in the supplementary material 2, and these results were consistent with the main findings (the relationship between smoking and sleep quality was prominent in women, especially those under middle age). Fifth, this study has limitations in validity or accuracy of the participants' responses. However, the KCHS was conducted in a standardized interviewing method by well-trained interviewers, and the questionnaires on depression mood, perceived stress and subjective health status has been widely used in previous many studies. Therefore, limitations on validity and accuracy can be minimized.

One of the major strengths of this study was that various sociodemographic factors, health behaviors, comorbidities, and psychologic factors that can be simultaneously related to smoking and sleep quality were reflected as confounding factors. The biggest strength of this study may be that the relationship between sleep quality evaluated using PSQI and smoking was analyzed in consideration of the interaction between sex and age in a large, nationally representative sample. Although some studies have analyzed sleep disorders in relation to sex or age, it is difficult to identify studies that consider sex and age simultaneously, especially using PSQI. This study on the relationship between PSQI and smoking according to sex and age could yield evidence for providing differentiated services or programs for those who suffer from sleep disorders.

The results of this study suggest that interventions for sleep disorders should preferentially include counseling and treatment for smoking cessation in women, especially those under middle age. These interventions should be administered simultaneously with solutions for psychological problems such as depression and stress.

340

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344 **AUTHOR CONTRIBUTIONS**

345 Conceptualization: SWP. Data curation: JHH. Formal analysis: SWP, JHH. Funding
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Table 1. Characteristics of participants and poor sleep quality in relation to the characteristics

Category	Subgroup	Study Population		Poor sleep quality (PSQI>5)	
		Unweighted N	Proportion (Weighted %)	Weighted %	95% CI
Total		224,986	100.0	39.4	(39.1-39.7)
Smoking frequency/amount	Non-smoker	185,975	79.8	39.6	(39.3-40.0)
	Occasional smoker & Daily smoker (<1 pack per day)	23,483	13.0	37.8	(37.0-38.5)
	Daily smoker (≥1 pack per day)	15,528	7.2	39.8	(38.8-40.8)
Socio-demographic factors					
Sex	Male	100,914	49.6	34.2	(33.8-34.6)
	Female	124,072	50.4	44.5	(44.2-44.9)
Age	19-35	37,947	26.6	35.2	(34.7-35.8)
	36-64	116,347	55.2	38.1	(37.7-38.4)
	≥ 65	70,692	18.2	49.5	(49.0-50.1)
Education level	≤ High school	156,702	58.4	42.8	(42.5-43.2)
	≥ College	68,284	41.6	34.6	(34.1-35.0)
Employment	No	86,075	36.4	45.0	(44.5-45.4)
	Yes	138,911	63.6	36.2	(35.9-36.6)
Health behavior factors					
Alcohol drinking within 1 year	Non-drinker	72,826	24.3	43.2	(42.7-43.8)
	≤1 per month	57,843	27.7	39.4	(38.8-39.9)
	2-4 per month	44,898	24.4	35.9	(35.4-36.5)
	2-3 per week	31,144	16.3	37.8	(37.1-38.5)
	≥4 per week	18,275	7.4	41.9	(41.0-42.9)
Walking exercise	<4 per week	124,913	50.2	41.2	(40.8-41.6)
	≥5 per week	100,073	49.8	37.6	(37.2-38.0)
Comorbidity					
Hypertension	No	161,054	79.6	37.5	(37.2-37.8)
	Yes	63,932	20.4	46.9	(46.4-47.5)
Diabetes	No	200,089	91.8	38.6	(38.3-38.9)
	Yes	24,897	8.2	49.0	(48.2-49.9)
Psychological factors					
Perceived stress level	little	55,127	19.4	29.9	(29.4-30.5)
	low	117,334	54.8	35.2	(34.8-35.5)
	high	44,854	22.0	53.4	(52.8-54.0)
	very high	7,671	3.7	67.9	(66.6-69.2)
Depressive mood	No	212,060	94.1	37.3	(37.0-37.6)
	Yes	12,926	5.9	73.5	(72.5-74.5)
Subjective health status	High	79,265	39.5	27.5	(27.1-27.9)
	Middle	100,026	45.9	42.4	(42.0-42.8)
	Low	45,695	14.5	62.1	(61.5-62.7)

Table 2. Unadjusted and adjusted odds ratios for poor sleep quality (PSQI > 5) using multiple logistic regression

Category	Subgroup	Male			Female		
		Crude OR (95% CI)	Adjusted OR ¹ (95% CI)	Adjusted OR ² (95% CI)	Crude OR (95% CI)	Adjusted OR ¹ (95% CI)	Adjusted OR ² (95% CI)
Smoking frequency/amount	Non-smoker	Reference	Reference	Reference	Reference	Reference	Reference
	Occasional smoker & Daily smoker (<1 pack per day)	1.09 (1.05-1.14)*	1.14 (1.09-1.19)*	1.04 (0.99-1.09)	1.96 (1.80-2.15)*	1.92 (1.75-2.11)*	1.50 (1.36-1.65)*
	Daily smoker (≥1 pack per day)	1.30 (1.24-1.36)*	1.27 (1.21-1.34)*	1.08 (1.02-1.14)*	2.45 (1.97-3.04)*	2.26 (1.82-2.82)*	1.45 (1.16-1.81)*
Socio-demographic factors							
Age	19-35	Reference	Reference	Reference	Reference	Reference	Reference
	36-64	1.14 (1.09-1.19)*	1.08 (1.04-1.13)*	1.01 (0.96-1.06)	1.11 (1.07-1.15)*	1.04 (1.00-1.08)	1.04 (1.00-1.09)
	≥ 65	1.47 (1.40-1.54)*	1.22 (1.15-1.30)*	1.28 (1.20-1.36)*	2.02 (1.94-2.11)*	1.52 (1.44-1.60)*	1.51 (1.43-1.61)*
Education level	≤ High school	1.24 (1.20-1.28)*	1.11 (1.07-1.15)*	1.12 (1.08-1.16)*	1.53 (1.49-1.59)*	1.23 (1.19-1.28)*	1.20 (1.16-1.25)*
	≥ College	Reference	Reference	Reference	Reference	Reference	Reference
Employment	No	1.23 (1.18-1.28)*	1.20 (1.14-1.25)*	1.13 (1.08-1.18)*	1.37 (1.33-1.41)*	1.18 (1.14-1.22)*	1.20 (1.16-1.24)*
	Yes	Reference	Reference	Reference	Reference	Reference	Reference
Health behavior factors							
Alcohol drinking within 1 year	Non-drinker	Reference	Reference	Reference	Reference	Reference	Reference
	≤1 per month	0.95 (0.90-1.00)*	1.05 (1.00-1.11)	1.11 (1.05-1.18)*	0.83 (0.80-0.86)*	1.03 (0.99-1.07)	1.05 (1.01-1.10)*
	2-4 per month	0.84 (0.80-0.89)*	0.96 (0.91-1.02)	1.06 (1.00-1.12)	0.81 (0.78-0.85)*	1.09 (1.04-1.14)*	1.15 (1.10-1.21)*
	2-3 per week	0.99 (0.94-1.05)	1.10 (1.04-1.17)*	1.20 (1.13-1.27)*	0.92 (0.87-0.97)*	1.20 (1.13-1.27)*	1.22 (1.15-1.30)*
	≥4 per week	1.23 (1.16-1.30)*	1.25 (1.17-1.32)*	1.28 (1.20-1.36)*	1.27 (1.15-1.41)*	1.43 (1.29-1.59)*	1.39 (1.24-1.55)*
Walking exercise	<4 per week	1.14 (1.11-1.18)*	1.13 (1.10-1.17)*	1.05 (1.01-1.09)*	1.17 (1.14-1.21)*	1.15 (1.12-1.19)*	1.06 (1.03-1.10)*
	≥5 per week	Reference	Reference	Reference	Reference	Reference	Reference

Comorbidity							
Hypertension	No	Reference	Reference	Reference	Reference	Reference	Reference
	Yes	1.30 (1.25-1.35)*	1.13 (1.08-1.18)*	1.01 (0.97-1.06)	1.71 (1.65-1.77)*	1.24 (1.19-1.29)*	1.09 (1.04-1.13)*
Diabetes	No	Reference	Reference	Reference	Reference	Reference	Reference
	Yes	1.40 (1.33-1.48)*	1.21 (1.14-1.28)*	1.01 (0.96-1.08)	1.79 (1.71-1.89)*	1.28 (1.21-1.35)*	1.06 (1.00-1.12)
Psychological factors							
Perceived stress level	little	Reference		Reference	Reference		Reference
	low	1.30 (1.24-1.36)*		1.39 (1.32-1.46)*	1.24 (1.20-1.29)*		1.43 (1.37-1.49)*
	high	2.58 (2.45-2.72)*		2.45 (2.31-2.60)*	2.83 (2.70-2.96)*		2.78 (2.64-2.91)*
	very high	5.03 (4.57-5.54)*		3.80 (3.42-4.21)*	5.11 (4.67-5.60)*		3.78 (3.41-4.18)*
Depressive mood	No	Reference		Reference	Reference		Reference
	Yes	4.90 (4.49-5.35)*		2.89 (2.64-3.17)*	4.19 (3.92-4.47)*		2.45 (2.29-2.63)*
Subjective health status	High	Reference		Reference	Reference		Reference
	Middle	1.83 (1.77-1.90)*		1.66 (1.59-1.72)*	1.97 (1.91-2.04)*		1.70 (1.64-1.76)*
	Low	3.62 (3.43-3.81)*		2.64 (2.49-2.79)*	4.67 (4.47-4.84)*		2.93 (2.79-3.09)*

OR, odds ratio; CI, confidence interval

* $p < 0.05$

¹ Adjusted for frequency of age, education level, employment, alcohol consumption, walking exercise, and history of hypertension or diabetes.

² Additionally adjusted for perceived stress level, depressive mood, and subjective health status to Model 1.

Table 3. Unadjusted and adjusted odds ratios for poor sleep quality (PSQI > 5) according to smoking status by sex and age group

Category	Subgroup	Male			Female		
		Crude OR (95% CI)	Adjusted OR ¹ (95% CI)	Adjusted OR ² (95% CI)	Crude OR (95% CI)	Adjusted OR ¹ (95% CI)	Adjusted OR ² (95% CI)
19-35	Non-smoker	Reference	Reference	Reference	Reference	Reference	Reference
	Occasional smoker & Daily smoker (<1 pack per day)	1.21 (1.11-1.31)*	1.15 (1.06-1.26)*	1.07 (0.97-1.16)	2.12 (1.80-2.50)*	2.00 (1.68-2.37)*	1.49 (1.24-1.79)*
	Daily smoker (≥1 pack per day)	1.59 (1.41-1.80)*	1.43 (1.26-1.62)*	1.15 (1.00-1.32)	3.43 (2.12-5.55)*	3.24 (2.00-5.25)*	1.53 (0.93-2.50)
36-64	Non-smoker	Reference	Reference	Reference	Reference	Reference	Reference
	Occasional smoker & Daily smoker (<1 pack per day)	1.12 (1.06-1.19)*	1.11 (1.05-1.18)*	1.01 (0.96-1.08)	2.24 (1.99-2.53)*	1.98 (1.75-2.23)*	1.56 (1.37-1.77)*
	Daily smoker (≥1 pack per day)	1.33 (1.25-1.41)*	1.23 (1.16-1.31)*	1.06 (1.00-1.13)	2.52 (1.93-3.30)*	2.07 (1.58-2.70)*	1.49 (1.14-1.95)*
≥65	Non-smoker	Reference	Reference	Reference	Reference	Reference	Reference
	Occasional smoker & Daily smoker (<1 pack per day)	1.11 (1.00-1.22)*	1.08 (0.98-1.19)	1.02 (0.92-1.13)	1.56 (1.22-1.98)*	1.53 (1.21-1.94)*	1.27 (0.99-1.62)
	Daily smoker (≥1 pack per day)	1.01 (0.89-1.15)	1.02 (0.90-1.16)	0.94 (0.82-1.08)	1.52 (0.93-2.49)	1.52 (0.93-2.50)	1.06 (0.60-1.87)

OR, odds ratio; CI, confidence interval

*p < 0.05

¹ Adjusted for frequency of age, education level, employment, alcohol consumption, walking exercise, and history of hypertension or diabetes.

² Additionally adjusted for perceived stress level, depressive mood, and subjective health status to Model 1.

Male
P for interaction=0.020

Female
P for interaction=0.232