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Physical activity, smoking and the incidence of clinically-diagnosed insomnia

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Abstract

Objective: This study was designed to examine the independent and combined associations of physical activity and smoking on incidence of doctor-diagnosed insomnia using a nationally representative sample over seven years, taking into account other relevant covariates.

Methods: Participants who aged 18 or older in the 2005 Taiwan National Health Interview Survey (NHIS) with links to National Health Insurance (NHI) claim data between 2005-2012, and without diagnosed insomnia before 2005, were selected into this study (n=12728). Participants were classified as having insomnia with ICD-9 CM codes: 307.41, 307.42, or 780.52. Self-reported smoking status and frequency, duration and types of leisure-time and non-leisure time physical activities were collected. Metabolic equivalent（MET）intensity levels for each activity were assigned and weekly energy expenditure of each activity was calculated and summed.

Results: Inactive participants had a higher risk of incident insomnia (HR=1.22, 95 % CI=1.06-1.42, p=0.007) than the active group, and ever-smokers were more likely to have incident insomnia than never smokers (HR=1.45, 95 % CI=1.20–1.76, p<0.001). Compared with the non-smoker/active group, the ever-smoker/inactive group had a higher risk of incident insomnia (HR=1.78, 95 % CI=1.41–2.25, p<0.001). Sensitivity analyses excluding individuals diagnosed with other sleep disorders or mental disorders yielded similar results, with the ever-smoker/inactive group having

the highest risk of insomnia.

Conclusions: Inactive adults and smokers are at higher risk for incident insomnia, highlighting the importance of a healthy lifestyle and pointing to strategies such as encouraging smoking cessation and physical activity in order to avoid insomnia among adults.

Key words: Sleep disorder, physical inactivity, exercise, unhealthy behavior, cigarette

Physical activity, smoking and the incidence of clinically-diagnosed insomnia

1. Introduction

Insomnia is a common psychological disorder and the estimated prevalence varies from 10-40% depending on definitions (1). Up to one-third of the general population report insomnia symptoms including difficulties initiating or maintaining sleep, and the average prevalence of diagnosed insomnia is around 6% (2). Insomnia is associated with an increased risk of adverse mental and physical health outcomes such as depression (3), cognitive impairment (4, 5), poor self-rated health (6), and cardiovascular disease (7), as well as an impaired quality of life (8).

Smoking is also linked to a number of negative health outcomes, including cancer, cardiovascular and pulmonary diseases, anxiety disorders or symptoms, and impaired memory (9-11). Moreover, smokers are more likely to report several insomnia-like sleep impairments (e.g. insufficient sleep, longer sleep latency, poorer sleep quality) than non-smokers (10, 12, 13). Longitudinal studies have found that adult smokers who began smoking in adolescence have an increased risk of insomnia (14) and continuous heavy smoking in women is associated with an increased likelihood of insomnia in late mid-life (15).

By contrast, physical activity appears to be beneficial for sleep and is associated with increased total sleep time and sleep efficiency, decreased sleep latency, and improved sleep quality (16, 17). It is thought that physical activity may be valuable for improving sleep outcomes among individuals

with sleep difficulties, as well as in those diagnosed with insomnia (18-20). It has also been suggested that physical activity may help reduce the incidence of insomnia symptoms (21, 22).

Most population studies investigating risk factors for insomnia incidence have used simple questions to define insomnia (21, 23), which may lead to some degree of misclassification. Formal diagnoses of insomnia provide a stronger basis on which to manage the condition, but epidemiological studies involving insomnia diagnoses are limited (2). One longitudinal study examined risk factors for diagnosed insomnia but focused on the demographic correlates of the condition and did not include physical activity or smoking status in the analyses (24)

Since physical inactivity, smoking and insomnia are associated with a range of physical and psychiatric disorders, understanding their relationship may help to promote public health. Additionally, if physical activity and not smoking are beneficial for sleep, combining the two behaviors may be valuable in the prevention of insomnia. This study was therefore designed to examine the independent and combined associations of physical activity and smoking on incidence of doctor-diagnosed insomnia using a nationally representative sample over seven years, taking into account other relevant covariates.

2. Methods

2.1 Study population

Participants were selected from the 2005 National Health Interview Survey (NHIS), conducted

by the National Health Research Institutes and Bureau of Health Promotion, Taiwan. This is a periodic nationwide survey using a multi-stage stratified systematic sampling design to select a nationally representative sample (25). A total of 24,726 participants were included in the 2005 NHIS with a response rate of 80.59%. The NHIS data were linked to the 2005-2012 claims data in the National Health Insurance (NHI) Research Database. The NHI is a public compulsory insurance system for all citizens covering over 99% of Taiwan's population (26, 27).

Participants who aged 18 or older in the NHIS (n=18529), provided the consent to link their NHI claim data (n=13926), and were not diagnosed with insomnia before 31 December 2005 were selected into this study (n=12728). The study was approved by Taichung Veterans General Hospital Institutional Review Board, Taiwan. To ensure adequate data protection, all data access and statistical analyses were conducted in the Health and Welfare Data Science Centre, Ministry of Health and Welfare, Taiwan.

2.2 Definition of clinical insomnia

Participants were classified as having insomnia if they had any of the following insomnia-related ICD-9 CM codes: 307.41, 307.42, or 780.52 based on the claim data from the NHI Research Database. Participants who were newly diagnosed as having insomnia between 2006-2012 and who had not been defined as having insomnia for at least 2 years before 31 December 2005 were considered incident cases. The date of diagnosis of insomnia was recorded.

2.3 Physical activity

Leisure-time and non-leisure time physical activity were self-reported in the 2005 NHIS. Leisure-time physical activity was assessed by the following question: 'Did you participate in any leisure-time physical activities during the last two weeks?'. Respondents were asked to identify the activity types they engaged in from 31 named activities (e.g. Tai Chi, walking, jogging, swimming etc.), and were able to specify up to five types. Frequency and duration for each activity were also collected, and metabolic equivalent (MET) intensity levels for each activity were assigned (28). Weekly energy expenditure (kcal) of each activity was calculated by: activity intensity code (kcal/min) × frequency per week (times) × duration for each time (min). These were then summed to provide a total weekly amount of energy expenditure for leisure-time activity.

Participants were also asked: 'Did you participate in any non-leisure time physical activity during the last two weeks?' They were asked to identify the activity types they engaged in from 10 named activities (e.g. farm or fishing work, heavy lifting, household chores) and could specify up to five types. The total weekly amount of energy expenditure for non-leisure time physical activity was calculated as described above. The leisure time and non-leisure time physical activity were then summed to provide weekly energy expenditure for overall physical activity, which was grouped into two levels (inactive: 0-999, active: ≥1000 kcal/week) based on international recommendations (29). These physical activity measures have been used in previous work (25, 30, 31).

2.4 Smoking status

The following questions were asked to assess smoking status in the 2005 NHIS: 'Have you ever smoked?' and 'Did you smoke during the past one month?'. Participants were classified as 'current smoker' if they reported they have ever smoked and smoked during the past month. Those who answered they had ever smoked but did not smoke during the past month (quit smoking) were classified as 'cormer smokers'. Others who have never smoked were grouped into 'never-smoker'. As the percentage of former-smokers was very small (4.7%), and only 57 of them were identified as developing insomnia, both the current and former smokers were combined and are subsequently referred to as 'ever-smokers'.

2.5 Covariates

The following variables in 2005 NHIS (at baseline) were selected as covariates based on previous research (23, 32): (1) socio-demographic variables: sex, age (18-44, 45-64, ≥65), education level (≤primary school, high school, ≥college), marital status (married/cohabitating, never married, others), monthly household income (US dollars) (<1000, 1000-2333, ≥2333); (2) health-related variables: alcohol consumption (yes vs. no), weight status (body mass index, BMI : <18.5, 18.5-23.9, 24-26.9, ≥27) (33), and the Charlson comorbidity index (0, 1-2, ≥3), which is based on the number and severity of diseases (34, 35).

2.6 Data analysis

Descriptive statistics for each variable at baseline in 2005 by insomnia incidence between 2006 and 2012 were calculated to characterize the sample structure. Chi-square analyses were performed to test differences between insomnia incidence and each variable.

Two separate Cox proportional hazards regressions were computed. The first regression tested the independent association of baseline physical activity and smoking status on 7-year insomnia incidence controlling for socio-demographic and health-related variables (model 1). To assess the combined associations between physical activity and smoking status on insomnia incidence, participants were categorized by smoking status across physical activity levels. Four groups were created: Non-smoker/Active, Non-smoker/Inactive, Ever-smoker/Active, and Ever-smoker/Inactive. A second regression was carried out to predict insomnia incidence by entering this classification with multivariate adjustments (model 2).

Given other sleep disorders or mental disorders may affect the associations between physical activity, smoking and insomnia (32), several sensitivity analyses were conducted. First, participants who were diagnosed with other sleep disorders including sleep apnea, restless legs syndrome, periodic limb movement disorder, or circadian rhythm sleep disorder before 31 December 2005 were excluded (n=10) (model 3 and 4). Additionally, those who were diagnosed with mental disorders including dementia, alcohol- or drug-induced mental disorders, schizophreniA, anxiety, or episodic mood disorders before 31 December 2005 were further excluded (n=1401) (model 5 and

6).

All analyses were performed using SAS 9.4 software and a p value < 0.05 was considered statistically significant.

3. Results

Table 1 provides information about characteristics of participants in 2005 at baseline and the rate of clinical insomnia incidence between 2006 and 2012. The prevalence of clinical insomnia was 5.7% in 2005 and the incidence of clinical insomnia was 6.6% from 2006 to 2012. Participants with incident insomnia were more likely to be older, female, less educated, had lower incomes and a higher burden of comorbidity than the remainder of the sample (all p<0.001). Overall, 63.4% of Taiwanese adults were not physically active and around one third (32.5%) were ever-smokers. Among the participants, 22.0% were categorized as non-smoker/active, 45.5% as non-smoker/inactive, 14.6% as ever-smoker/active, and 17.9% as ever-smoker/inactive. Participants who were not physically active had a higher rate of incident insomnia (p=0.010). No difference was found in insomnia incidence between non-smokers and ever-smokers in univariate analyses (p=0.801), but participants in the ever-smoker/inactive group had the highest rate of incident insomnia than the comparison groups (p=0.015).

Table 1

Table 2 shows the independent and combined associations of physical activity and smoking on

the incidence of diagnosed insomnia by Cox regression with fully adjusted models. Inactive participants had a higher risk of incident insomnia (HR =1.22, 95 % CI =1.06–1.42, p=0.007) than the active group (model 1). Similarly, ever-smokers were more likely to have incident insomnia than never smokers (HR =1.45, 95 % CI =1.20–1.76, p<0.001). The overall effect of combined physical activity and smoking on incident insomnia was significant (p<0.001). Compared with the non-smoker/active group, the ever-smoker/inactive group had a higher risk of incident insomnia (HR =1.78, 95 % CI =1.41–2.25, p<0.001, model 2).

Apart from physical activity and smoking, participants who were older, female, married, underweight, with high school rather than college education, and a higher burden of comorbidity had a higher rate of clinical insomnia than the reference groups (all p< 0.05).

Table 2

The sensitivity analyses excluding patients diagnosed with other sleep disorders or mental disorders before 31th December 2015 yielded similar results for physical activity and smoking (table 3). Inactive participants and ever-smokers both had higher risk of incident insomnia than the comparison groups after excluding patients diagnosed with other sleep disorders (HR =1.22, 95 % CI =1.05–1.42, p=0.008; HR =1.44, 95 % CI =1.20–1.75, p<0.001, respectively, model 3). The combination of physical inactivity and smoking also showed a significant effect on incident insomnia, with the ever-smoker/inactive group having the highest risk of insomnia (HR =1.77, 95 %

CI =1.40–2.23, $p<0.001$, model 4). Further exclusion of individuals diagnosed with mental disorders did not alter these associations between clinical insomnia, physical inactivity and smoking (models 5 and 6).

Table 3

4. Discussion

This population-based seven-year follow-up study revealed that the majority of participants were not physically active and around one third were current or former smokers. The prevalence of clinically diagnosed insomnia was 5.7% in 2005, and this is consistent with other population estimates (2). The incidence of clinical insomnia was 6.6% over the 7-year follow-up period. Inactive individuals or ever-smokers had higher risks of subsequent clinically diagnosed insomnia compared with the active group or non-smokers. The highest risk of incident insomnia was observed among ever-smokers who were inactive. Sensitivity analyses that excluded individuals diagnosed with other sleep disorders or mental disorders provided further evidence for the robustness of these findings.

The beneficial effects of physical activity on sleep outcomes were conformed. Many previous studies have involved structured aerobic exercise programs in relatively small samples (16, 17, 19, 36). Epidemiological studies examining the association of physical activity and incident insomnia are limited and several have focused on older adults (21, 22). Although the age range and definition

of physical activity and insomnia varied between this study and previous work, similar results were found with respect to low physical activity and the risk of insomnia. There are several plausible pathways through which greater physical activity might lead to better sleep. For example, physical activity depletes energy stores, so may increase the need for sleep in order to reduce metabolic requirements for energy conservation and/or body restoration (37). Moreover, active individuals tend to be less obese, have better health outcomes and quality of life, as well as better mood, all of which are associated with better sleep (18, 38, 39).

Significant associations between smoking and sleep disturbances or insomnia have also been reported (15, 40, 41). Our findings are consistent with previous results even though we used strict diagnostic criteria for insomnia, suggesting that smokers are at increased risk. Possible mechanisms that have been proposed include the activating effects of nicotine and the associations with depressive symptoms or health conditions among smokers (13, 15, 40, 41). However, our study controlled several potential confounders including medical conditions and also further excluded patients with mental disorders in the sensitivity analyses, and the association between smoking and incident insomnia remained.

No previous studies have examined the combination of physical activity and smoking in relation to incident insomnia. Our results showed that inactive smokers had the highest risk of insomnia and active smokers had a lower rate of insomnia compared with inactive smokers. This

suggests that promoting physical activity among smokers might help to prevent the development of clinical insomnia. Smoking prevalence is generally higher among disadvantaged groups (42) and heavy smokers tend to engage in more unhealthy behaviors such as poor dietary choice and inactive and sedentary behaviors (43). Research indicates that active smokers are more likely to engage in inexpensive, low-intensity, and solitary leisure-time physical activities than in formal organized exercise programs (44). This should be taken into account when promoting physical activity among smokers for the prevention of insomnia.

Some limitations should be taken into account when evaluating these findings. Insomnia is a patient-reported symptom (45). In this study, insomnia was clinically diagnosed, but other research shows that only 30-42% of patients with sleep difficulties have consulted physicians for sleep problems (46, 47). Our findings may therefore have underestimated the actual incidence in the population and might not generalize to those who without clinically diagnosed with insomnia. Although we excluded people with diagnosed insomnia, we did not have ratings of sleep difficulties at baseline. Physical activity volume was computed from self-reported frequency, duration, and intensity, which may have been susceptible to recall bias. The rates of smoking were higher than in many Western populations, and there were not enough former smokers to analyze as a separate group. Finally, this study did not collect information about physical pain, fatigue, or menstrual status, which may impact on insomnia (32), although we did take medical comorbidity, mental

disorders, and other sleep disorders into account.

In sum, this study examined the independent and combined associations of physical activity and smoking on the incidence of diagnosed insomnia adjusting for potential confounders with a nationally representative sample across seven years. It suggests that inactive adults and smokers are at higher risk for incident insomnia. It also highlights the importance of a healthy lifestyle and points to strategies such as encouraging smoking cessation and physical activity in order to avoid insomnia among adults.

Ethical approval

This study was approved by the Taichung Veterans General Hospital Institutional Review Board, Taiwan (reference number: SE14257A-1). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Highlights

- Inactive adults or ever-smokers are at higher risk of developing clinical insomnia than active adults or non-smokers.
- The highest risk of incident insomnia was observed among ever-smokers who were inactive.
- It is important to maintain a healthy lifestyle, including not smoking and being physically active, to avoid insomnia.

Table 1. Characteristics of participants in 2005 by insomnia incidence 2006-2012

Variables (n=12728)	n	Insomnia incidence		
		n	%	p-value [a]
Age				<0.001
18-44	7675	352	(4.6)	
45-64	3614	331	(9.2)	
≥ 65	1439	162	(11.3)	
Sex				<0.001
Female	5929	491	(8.3)	
Male	6799	354	(5.2)	
Education				<0.001
≥ College	4148	167	(4.0)	
High school	5708	392	(6.9)	
≤ Primary school	2872	286	(10.0)	
Marital status				<0.001
Married/cohabiting	7643	583	(7.6)	
Never Married	3912	144	(3.7)	
Others	1173	118	(10.1)	
Monthly household income (US dollar)				<0.001
≥ 2333	4060	237	(5.8)	
1000-2333	5343	336	(6.3)	
< 1000	3325	272	(8.2)	
Weight status (BMI)				0.170
Normal (18.5-23.9)	6795	438	(6.4)	
Underweight (<18.5)	904	70	(7.7)	
Overweight (24-26.9)	2948	183	(6.2)	
Obese (≥27)	2081	154	(7.4)	
Charlson Comorbidity Index				<0.001
0	9831	528	(5.4)	
1-2	2395	262	(10.9)	
≥3	502	55	(11.0)	
Alcohol consumption				<0.001
No	7861	584	(7.4)	
Yes	4867	261	(5.4)	
Active smoking				0.801
Non-smoker	8596	574	(6.7)	
Ever-smoker	4132	271	(6.6)	
Overall PA (kcal/week)				0.010
1000+ (active)	4655	274	(5.9)	
0-999 (inactive)	8073	571	(7.1)	
Smoking_PA				0.015
Never-smoker_ Active	2802	177	(6.3)	
Never-smoker_ Inactive	5794	397	(6.9)	
Ever-smoker _Active	1853	97	(5.2)	
Ever-smoker _ Inactive	2279	174	(7.6)	

a: Chi-square tests

Table 2. Associations of PA and smoking on insomnia incidence by Cox regression

Variables (n=12728)	Model 1			Model 2		
	HR	95% CI	P-value	HR	95% CI	P-value
Age			<0.001†			<0.001†
18-44	1.00	—	—	1.00	—	—
45-64	1.69	(1.40-2.03)	<0.001	1.68	(1.40-2.03)	<0.001
≥ 65	2.11	(1.63-2.73)	<0.001	2.11	(1.63-2.73)	<0.001
Sex						
Female	1.00	—	—	1.00	—	—
Male	0.57	(0.48-0.69)	<0.001	0.57	(0.48-0.69)	<0.001
Education			0.001†			0.001†
≥ College	1.00	—	—	1.00	—	—
High school	1.44	(1.18-1.75)	<0.001	1.44	(1.18-1.75)	<0.001
≤ Primary school	1.27	(0.99-1.63)	0.064	1.26	(0.98-1.62)	0.070
Marital status			0.015†			0.015†
Married/cohabiting	1.00	—	—	1.00	—	—
Never Married	0.73	(0.59-0.90)	0.004	0.73	(0.59-0.90)	0.004
Others	0.99	(0.81-1.23)	0.960	0.99	(0.81-1.23)	0.953
Monthly household income (US dollars)			0.500†			0.524†
≥ 2333	1.00	—	—	1.00	—	—
1000-2333	0.90	(0.76-1.07)	0.242	0.91	(0.76-1.08)	0.257
< 1000	0.94	(0.78-1.15)	0.567	0.94	(0.78-1.15)	0.563
Weight status (BMI)			0.022†			0.021†
Normal (18.5-23.9)	1.00	—	—	1.00	—	—
Underweight (<18.5)	1.37	(1.06-1.77)	0.017	1.37	(1.06-1.77)	0.017
Overweight (24-26.9)	0.87	(0.73-1.03)	0.114	0.87	(0.73-1.03)	0.112
Obese (≥27)	0.98	(0.82-1.19)	0.870	0.99	(0.82-1.19)	0.889
Charlson Comorbidity Index			<0.001†			<0.001†
0	1.00	—	—	1.00	—	—
1-2	1.69	(1.45-1.98)	<0.001	1.69	(1.44-1.97)	<0.001
≥3	1.76	(1.32-2.36)	<0.001	1.76	(1.31-2.35)	<0.001
Alcohol consumption						
No	1.00	—	—	1.00	—	—
Yes	0.85	(0.72-1.00)	0.050	0.85	(0.72-1.00)	0.052
Active smoking						
Non-smoker	1.00	—	—			
Ever-smoker	1.45	(1.20-1.76)	<0.001			
Overall PA (kcal/week)						
1000+ (active)	1.00	—	—			
0-999 (inactive)	1.22	(1.06-1.42)	0.007			
Smoking_ PA						<0.001†
Non-smoker_ Active				1.00	—	—

Non-smoker_ Inactive	1.14	(0.95-1.36)	0.157
Ever-smoker_ Active	1.27	(0.97-1.67)	0.087
Ever-smoker_ Inactive	1.78	(1.41-2.25)	<0.001

† p-value for the overall effect of a variable

Table 3. Sensitivity analyses for predicting risks of insomnia incidence

Variables	Model 3 (n=12718)			Model 4 (n=12718)			Model 5 (n=11317)			Model 6 (n=11317)		
	HR	95% CI	P-value	HR	95% CI	P-value	HR	95% CI	P-value	HR	95% CI	P-value
Active smoking												
Non-smoker	1.00	—	—				1.00	—	—			
Ever-smoker	1.44	(1.20-1.75)	<0.001				1.55	(1.25-1.92)	<0.001			
Overall PA (kcal/week)												
1000+ (active)	1.00	—	—				1.00	—	—			
0-999 (inactive)	1.22	(1.05-1.42)	0.008				1.19	(1.01-1.41)	0.039			
Smoking_ PA						<0.001†						<0.001†
Non-smoker_ Active				1.00	—	—				1.00	—	—
Non-smoker_ Inactive				1.14	(0.95-1.36)	0.156				1.11	(0.90-1.37)	0.335
Ever-smoker_ Active				1.27	(0.96-1.67)	0.091				1.36	(0.99-1.85)	0.055
Ever-smoker_ Inactive				1.77	(1.40-2.23)	<0.001				1.85	(1.41-2.42)	<0.001

Model 3 & 4: Based on Model 1& 2, excluding patients diagnosed with other sleep disorders（Sleep apnea 327.23, 780.57; Periodic limb movement disorder 327.51; Restless legs syndrome 333.94; Circadian rhythm sleep disorder, 327.36, 780.55）before 2005.12.31

Model 5 & 6: Based on Model 1& 2, excluding patients diagnosed with other sleep disorders（Sleep apnea 327.23, 780.57; Periodic limb movement disorder 327.51; Restless legs syndrome 333.94; Circadian rhythm sleep disorder, 327.36, 780.55）or mental disorders (Dementia 290, Alcohol-induced mental disorders 291, Drug-induced mental disorders 292, Schizophrenic disorders 295, Episodic mood disorders 296, Anxiety, dissociative and somatoform disorder 300) before 2005.12.31

Covariates: all variables listed in Table 2

† p-value for the overall effect of a variable