

Association Between Sleep Quality and Falls: A Nationwide Population-Based Study from South Korea

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Purpose: There are few large studies evaluating the association between sleep quality and the risk of falls. We aimed to determine the independent effect of poor sleep quality on an increased risk of falls using a large-sample dataset.

Methods: We conducted a retrospective, cross-sectional study using population-based data from the 2018 Korean Community Health Survey on 201,700 participants. Sociodemographic, mental health-related, and physical health-related variables as well as sleep quality evaluated by the Pittsburgh Sleep Quality Index (PSQI) were compared between 2499 fallers who have experienced at least one fall during the past 12 months and 199,201 non-fallers. Multivariable logistic regression was performed to identify sleep quality variables significantly associated with an increased risk of falls.

Results: Fallers had poorer sleep quality (PSQI score >5) and higher scores for global PSQI and individual PSQI components than did non-fallers (all $p < 0.001$). Multivariable logistic regression adjusted for potential confounders including socioeconomic, physical health-related, and mental health-related variables showed that an increased risk of falls was associated with poor sleep quality (odds ratio [OR] 1.30, 95% confidence interval [CI] 1.19–1.42). Subgroup analyses by age revealed that poor sleep quality was significantly associated with an increased risk of falls in all three adult age groups. Multivariable logistic regression using the seven PSQI components revealed that an increased risk of falls was associated with short sleep duration (OR 1.14, CI 1.09–1.20), increased sleep disturbances (OR 1.30, CI 1.16–1.46), and increased daytime dysfunctions (OR 1.21, CI 1.08–1.13).

Conclusion: Poor sleep quality caused by short sleep duration may be a principal risk factor of falls in adult populations. Increased sleep disturbances and daytime dysfunctions may also contribute to an increased risk of falls. Our results have clinical and public health perspectives that increasing sleep duration and reducing daytime dysfunctions and sleep disturbances could mitigate unintentional falls.

Keywords: falls, sleep quality, Pittsburgh sleep quality index

Introduction

Falls pose a global public health concern and are a leading cause of both fatal and non-fatal unintentional injuries, deaths, and premature nursing home placement, especially in the older adult population.^{1–4} Approximately one-third of community-dwelling older adults and more than half of those living in nursing homes fall every year, and about half of those fallers fall repetitively.^{5,6} Both the incidence and severity of falls increase with age and increased disability and functional impairment.^{6,7} The high incidence, long-term consequences, and medical costs

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associated with both fatal and non-fatal fall-related injuries place a significant burden on the national health-care system.^{8,9}

Factors known to increase the risk of falls include older age, obesity, osteoporosis, cognitive impairment and dementia, Parkinson's disease, history of stroke, and alcohol consumption.^{10–13} Various sleep problems such as insomnia,^{14,15} insufficient sleep,^{13,16} increased sleep fragmentation,¹⁶ and excessive daytime sleepiness,¹⁷ could also be responsible for the increased risk of falls. Notably, former studies consistently showed that short sleep duration is a principal risk factor of falls and fall-related injuries in older adults^{13,16,18,19} and adolescents.^{20–22} Poor sleep quality resulting from diverse sleep disturbances may lead to excessive daytime sleepiness, daytime psychomotor impairment, and decreased attention and cognitive performance,^{23–25} thereby eventually resulting in an increased risk of falls and fall-related injuries.^{26,27}

Although sleep quality has been widely utilized in the fields of sleep science and medicine, this term lacks a definitional consensus.^{28,29} Sleep quality is generally referred to as a constellation of sleep measures including sleep latency and duration, sleep efficiency, sleep fragmentation, and disruptive nocturnal events such as apneas, abnormal behaviors, or arousals.²⁸ Good sleep quality is a well-known indicator of mental health, physical health, and overall vitality, and efforts have recently been made on providing scientifically sound recommendations with respect to indicators of good sleep quality.³⁰ The Pittsburgh Sleep Quality Index (PSQI) is the most extensively used self-administered questionnaire for assessment of sleep quality and patterns during the past month.³¹ It provides a reliable and standardized measure to discriminate good sleepers from poor sleepers, and has high internal consistency and strong test-retest reliability and validity.³² Notwithstanding the increased recognition of poor sleep quality as an important risk factor for falls, very few studies have investigated this association using population-representative samples.³³ In this population-based study using a large-sample dataset, we investigated the effect of sleep quality and disturbances measured by the PSQI on the risk of falls among a cohort of adults aged ≥ 19 years. We predicted that poor sleep quality may be associated with an increased risk of falls, independent of confounders such as socioeconomic, physical health-related, and mental health-related variables.

Materials and Methods

Study Population and Data

For this study, we acquired data from the 2018 Korean Community Health Survey (KCHS), a nationwide cross-sectional survey carried out by the Korea Centers for Disease Control and Prevention. This community-based health interview survey is conducted annually since 2008 by 254 community health centers from the 17 metropolitan cities and provinces, 35 community colleges, and 1500 interviewers, in order to explore the patterns of personal lifestyle, mental and physical health-related behaviors, and disease prevalence and morbidity in adults aged ≥ 19 years (the minimum age for adult in South Korea).³⁴ The sample size for each of the 254 community units is 900 participants, and the expected number of respondents in this survey is 228,600. The KCHS employed a two-stage sampling process to ensure that the sample units are representative of the general population.³⁵ The first stage involves selection of a sample area (tong/ban/ri) as a primary sample unit according to the number of households using a probability proportional to size sampling technique. The second stage of sampling process includes selection of sample households in each sample area using systematic sampling methods. To ensure the samples to be statistically representative of the general population, the survey data were weighted by reference to the sampling design.

Exclusion criteria were the following: (1) uninhabitable areas owing to redevelopment or reconstruction; (2) households in the nonresidential areas (eg, business district, industrial complex); (3) residences for specific groups (eg, lepers colony, dormitory, religious communities); and (4) households where the interviewer could not contact the family members after visiting the household more than three times. Data were collected by technicians trained in conducting computer-assisted in-person interviews. Among a total of 228,340 participants in the 2018 KCHS, 26,640 were excluded because they did not fill out the questionnaire variables listed in [Tables 1](#) and [2](#). Accordingly, 201,700 participants without missing variables were finally selected for the statistical analysis in this study.

The KCHS data are publicly available, and all data are completely anonymized before its release. This study was exempted from the need for an Institutional Review Board review since it did not correspond to research on human participants, according to Article 2.2 of the Enforcement Rule of Bioethics and Safety Act in Korea. All procedures of the survey were conducted in accordance with the

Table 1 Baseline Characteristics of the Fallers and Non-Fallers

	Fallers (n = 2499)	Non-Fallers (n = 199,201)	p-value
Age (y)	59.6 ± 17.5	53.1 ± 17.0	<0.001
Sex			
Male	908 (36.3)	93,059 (46.7)	<0.001
Female	1591 (63.7)	106,142 (53.3)	
Body mass index (kg/m²)	23.7 ± 3.5	23.7 ± 3.4	0.897
Residence area			
Urban	1367 (54.7)	117,460 (59.0)	<0.001
Rural	1132 (45.3)	81,741 (41.0)	
Education			
Elementary school or lower	899 (36.0)	40,651 (20.4)	<0.001
Middle school	373 (14.9)	23,069 (11.6)	
High school	597 (23.9)	59,688 (30.0)	
College or higher	630 (25.2)	75,793 (38.0)	
Marital status			
Married (living with spouse)	1529 (61.2)	137,046 (68.8)	<0.001
Living alone (never married, separated, divorced, widowed)	970 (38.8)	62,155 (31.2)	
Employment status			
Employed	1276 (51.1)	126,565 (63.5)	<0.001
Unemployed	1223 (48.9)	72,636 (36.5)	
Household income			
Low	1000 (40.0)	52,147 (26.2)	<0.001
Middle low	693 (27.7)	56,522 (28.4)	
Middle high	490 (19.6)	55,917 (28.1)	
High	316 (12.6)	34,615 (17.4)	
Smoking			
Current smoker	399 (16.0)	35,925 (18.0)	0.004
Non-smoker, ex-smoker	2100 (84.0)	163,276 (82.0)	
Risky drinker			
Yes	571 (22.8)	55,618 (27.9)	<0.001
No	1928 (77.2)	143,583 (72.1)	
Regular exercise			
Yes	1016 (40.7)	90,471 (45.4)	<0.001
No	1483 (59.3)	108,730 (54.6)	
Hypertension			
Yes	900 (36.0)	53,032 (26.6)	<0.001
No	1599 (64.0)	146,169 (73.4)	
Diabetes mellitus			
Yes	384 (15.4)	21,154 (10.6)	<0.001
No	2115 (84.6)	178,047 (89.4)	
Subjective cognitive decline			
Yes	681 (27.3)	34,860 (17.5)	<0.001
No	1818 (72.7)	164,341 (82.5)	
Perceived stress			
Yes	677 (27.1)	46,602 (23.4)	<0.001
No	1822 (72.9)	152,599 (76.6)	

(Continued)

Table 1 (Continued).

	Fallers (n = 2499)	Non-Fallers (n = 199,201)	p-value
Perceived health status			
Good	596 (23.8)	72,736 (36.5)	<0.001
Moderate	1030 (41.2)	90,015 (45.2)	
Bad	873 (34.9)	36,450 (18.3)	
PHQ-9 global score	3.4 ± 4.3	2.1 ± 3.1	<0.001
Depression			
Yes (PHQ9 score ≥ 10)	209 (8.4)	6709 (3.4)	<0.001
No (PHQ9 score 0–9)	2290 (91.6)	192,492 (96.6)	

Note: Data are presented as number (percent) or mean ± standard deviation.**Abbreviation:** PHQ-9, Patient Health Questionnaire-9.

ethical standards of the National Research Committee and the 1964 Helsinki Declaration and its later amendments.

Measures

Assessment of Falls

Falls were determined by asking the question: “Have you experienced at least one fall and slip over the last 12 months?” The responses were either yes or no.

Assessment of Sleep Quality

Sleep quality was assessed using the Korean version of the PSQI, which was validated with a high specificity and sensitivity.³⁶ Specifically, the PSQI comprises 19 items regarding seven sleep components: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction.³¹ Each component was scored on a scale ranging from 0 to 3. A global PSQI score for the assessment of overall sleep quality can be determined by adding all seven component scores, resulting in a final score ranging from 0 to 21. A global PSQI score of 5 or below generally indicates good sleep, and a score of 6 or above indicates poor sleep.^{37,38} Both global score and seven component scores of the PSQI were used in the statistical analyses.

Covariates

Sociodemographic variables included sex, age, body mass index, residence area (urban or rural), education level (elementary school or lower, middle school, high school, or college or higher), marital status (living with spouse or living alone), employment status (employed or unemployed), and household income (low, middle-low, middle-high, or high).^{39–42}

Table 2 Comparisons of the PSQI Scores Between Fallers and Non-Fallers

	Fallers (n = 2499)	Non-Fallers (n = 199,201)	p-value
PSQI global score	5.8 ± 3.4	4.7 ± 2.9	<0.001
Good sleep (PSQI ≤ 5)	1400 (56.0)	139,704 (70.1)	<0.001
Poor sleep (PSQI > 5)	1099 (44.0)	59,497 (29.9)	
Sleep quality			<0.001
0: very good	278 (11.1)	29,376 (14.7)	
1: fairly good	1357 (54.3)	124,934 (62.7)	
2: fairly bad	705 (28.2)	38,395 (19.3)	
3: very bad	159 (6.4)	6496 (3.3)	
Sleep latency (score)			<0.001
0: 0	926 (37.1)	91,978 (46.2)	
1: 1–2	706 (28.3)	59,184 (29.7)	
2: 3–4	447 (17.9)	27,061 (13.6)	
3: 5–6	420 (16.8)	20,978 (10.5)	
Sleep duration (h)			<0.001
0: > 7	463 (18.5)	35,400 (17.8)	
1: 6–7	1228 (49.1)	113,708 (57.1)	
2: 5–6	453 (18.1)	32,613 (16.4)	
3: < 5	355 (14.2)	17,480 (8.8)	
Sleep efficiency (%)			<0.001
0: ≥ 85	2163 (86.6)	183,623 (92.2)	
1: 75–84	234 (9.4)	11,420 (5.7)	
2: 65–74	66 (2.5)	2589 (1.3)	
3: ≤ 65	36 (1.4)	1569 (0.8)	
Sleep disturbance (score)			<0.001
0: 0	227 (9.1)	35,458 (17.8)	
1: 1–9	1661 (66.5)	138,882 (69.7)	
2: 10–18	574 (23.0)	23,959 (12.0)	
3: 19–27	37 (1.5)	902 (0.5)	
Use of sleeping medication			<0.001
0: not during the past month	2318 (92.8)	191,273 (96.0)	
1: less than once a week	46 (1.8)	2112 (1.1)	
2: once or twice a week	38 (1.5)	1633 (0.8)	
3: three or more times a week	97 (3.9)	4183 (2.1)	
Daytime dysfunction			<0.001
0: very good	1550 (62.0)	136,814 (68.7)	
1: fairly good	547 (21.9)	40,672 (20.4)	
2: fairly bad	323 (12.9)	18,238 (9.2)	
3: very bad	79 (3.2)	3477 (1.7)	

Note: Data are presented as number (percent) or mean ± standard deviation.

Abbreviation: PSQI, Pittsburgh Sleep Quality Index.

Physical health-related variables included risky drinking (12 or more drinking episodes in which five or more alcoholic glasses were consumed during the last year),⁴³ smoking status (current smoker or non-smoker/ex-smoker), regular exercise (at least 30 min of walking for at least 5 days per week),⁴⁴ and presence of hypertension and diabetes mellitus.^{42,45}

Mental health-related variables included perceived stress, perceived health status, subjective cognitive decline (SCD), and depression.^{40,41,46} Perceived stress was assessed by asking the following question: “How stressed do you feel in your daily life?” The responses were categorized as yes (severe or very severe) or no (rare or mild). Perceived health status was assessed by asking the following question, “How do you rate your health status in general?” The responses were categorized as good (very good or good), moderate, or bad (bad or very bad). According to the cognitive decline module of the Behavioral Risk Factor Surveillance System,⁴⁷ SCD was determined by asking the single question, “Have you experienced frequent or worsening of memory loss or confusion during the last year?” The responses were either yes or no. Depressive symptoms were evaluated by the Patient Health Questionnaire-9 (PHQ-9), a widely adopted scale in population-based studies.⁴⁸ The Korean version of the PHQ-9 used in this survey was validated previously.⁴⁹ Nine items were measured to evaluate depressive symptoms during the past two weeks and were scored on a scale ranging from 0 to 3 (0 = none, 1 = several days, 2 = more than 7 days, 3 = nearly every day). A global PHQ-9 score of ≥10 indicates the presence of depression.

Statistics

Descriptive statistics illustrated the baseline characteristics of the study population. Sociodemographic, physical health-related, and mental health-related variables as well as sleep quality measures (PSQI scores) were compared between fallers and non-fallers using the Student’s *t*-test, chi-square test, or Fisher’s exact test, where appropriate.

Multivariable logistic regression was performed to determine the effects of overall sleep quality (ie, good vs poor sleep) on falls. Model 1 was adjusted for sex, age, and body mass index. Model 2 was adjusted for Model 1 variables and socioeconomic variables (residence area, education level, marital status, employment status, and household income). Model 3 was adjusted for Model 2 variables and physical health-related variables (risky drinking, smoking, regular exercise, hypertension, and diabetes mellitus) and mental health-related variables (perceived status of health, perceived level of stress, SCD, and depression). In addition, multivariable logistic regression using the seven PSQI components was carried out to determine which component factor is more closely associated with an increased risk of falls. For statistical

analysis, each component score was categorized as good/less (0–1) and bad/more (2–3).

Given that the risk factor of falls and the effect of sleep quality on falls may be different according to age groups, subgroup analyses using multivariable logistic regression were further performed for three adult age groups: young adults aged 19–39 years, middle-aged adults aged 40–59 years, and older adults aged ≥ 60 years. Results were expressed as adjusted odds ratios (ORs) and 95% confidence intervals (CIs). A $p < 0.05$ indicates statistical significance in all tests. Statistical analyses were conducted using the Statistical Package for Social Sciences (version 25.0; IBM, Armonk, NY).

Results

The baseline characteristics of 2499 fallers and 199,201 non-fallers are presented in Table 1. Fallers were more likely to be female, older, living alone, unemployed, living in rural areas, and to have lower levels of household income and education than were non-fallers (all $p < 0.001$). Current smokers ($p = 0.004$), risky drinkers ($p < 0.001$), and regular exercisers ($p < 0.001$) were more frequently observed in non-fallers than in fallers. Fallers were found to have higher perceived stress, poorer perceived health status, and higher prevalence of hypertension, diabetes mellitus, SCD, and depression than were non-fallers (all $p < 0.001$).

Comparisons of the global PSQI score and each component score between the groups are summarized in Table 2. The global PSQI score was higher in fallers than in non-fallers (5.8 ± 3.4 vs 4.7 ± 2.9 , $p < 0.001$). As expected, poor sleeper (PSQI score >5) was more prevalent in fallers than in non-fallers (44.0% vs 29.9%, $p < 0.001$). The scores for all seven PSQI components were higher in fallers compared with non-fallers (all $p < 0.001$), indicating that fallers had poorer overall sleep quality than did non-fallers.

Table 3 shows the independent effect of sleep quality variables measured by the PSQI on the risk of falls after adjustment for sex, age, and body mass index (Model 1); Model 1 variables and socioeconomic variables (Model 2); and Model 2 variables and physical and mental health-related variables (Model 3). Compared to good sleep quality (reference), poor sleep quality (PSQI score >5) was significantly associated with an increased risk of falls (Model 1: OR 1.62, CI 1.49–1.76; Model 2: OR 1.53, CI 1.41–1.66; Model 3: OR 1.30, CI 1.19–1.42). No significant interactions were observed between the PSQI and the other covariates (all $p > 0.05$). The fully adjusted model

(Model 3) using the seven PSQI components confirmed that an increased risk of falls was significantly associated with short sleep duration (OR 1.14, CI 1.09–1.20), increased sleep disturbances (OR 1.30, CI 1.16–1.46), and increased daytime dysfunctions (OR 1.21, CI 1.08–1.13).

Table 4 summarizes the results of subgroup analyses by age. Fallers and poor sleepers (PSQI score >5) were more frequently observed in older adults than in young and middle-aged adults (both $p < 0.001$). A statistically significant step-wise increase in the global PSQI score was found from young adults to older adults (one-way ANOVA followed by Bonferroni correction, all $p < 0.001$). Compared to good sleep quality, poor sleep quality (PSQI score >5) was significantly associated with an increased risk of falls in all three age groups: young adults (Model 1: OR 1.42, CI 1.15–1.75; Model 2: OR 1.36, CI 1.10–1.67; Model 3: OR 1.29, CI 1.03–1.61), middle-aged adults (Model 1: OR 1.76, CI 1.51–2.05; Model 2: OR 1.64, CI 1.41–1.92; Model 3: OR 1.44, CI 1.22–1.71), and older adults (Model 1: OR 1.54, CI 1.39–1.72; Model 2: OR 1.49, CI 1.34–1.66; Model 3: OR 1.26, CI 1.13–1.42).

Discussion

In this study, we evaluated the association between the risk of falls and sleep quality measured by the PSQI among a cohort of adults aged ≥ 19 years. The main finding is that overall poor sleep quality independently contributed to an increased risk of falls in adult populations even after adjustment for potential confounders, although the effect of poor sleep quality on the risk of falls was alleviated as more confounders were included in the statistical models. The results of subgroup analyses according to adult age groups were substantially identical to that of the whole adult population. This study also indicated that an increased risk of falls was significantly associated with several components of sleep quality including short sleep duration, increased sleep disturbances, and increased daytime dysfunctions.

Previous studies have investigated the association between the risk of falls and sleep-related variables. The majority of the studies have focused on sleep duration and found that short sleep duration escalates the incident falls and injuries in the older adult population.^{13,16,18,19} Older women who are sleeping ≤ 5 h exhibited a 1.8-fold greater risk of falls relative to those sleeping 7–8 h.¹⁶ Likewise, adults who slept <7.5 h had a 1.6-fold greater risk of injuries relative to those sleeping 7.5–8.5 h.¹⁸ However, this association was not replicated in others.^{50,51}

Table 3 Results of Multivariable Logistic Regression Analysis Showing Associations Between the PSQI Scores and the Risk of Falls

	Model 1		Model 2		Model 3	
	OR	95% CI	OR	95% CI	OR	95% CI
PSQI						
Good sleep (PSQI ≤ 5)	1	Reference	1	Reference	1	Reference
Poor sleep (PSQI > 5)	1.62	1.49–1.76	1.53	1.41–1.66	1.30	1.19–1.42
Subjective sleep quality						
0–1	1	Reference	1	Reference	1	Reference
2–3	1.25	1.13–1.39	1.23	1.11–1.36	1.11	1.00–1.23
Sleep latency						
0–1	1	Reference	1	Reference	1	Reference
2–3	1.09	0.99–1.21	1.06	0.95–1.17	1.04	0.94–1.15
Sleep duration						
0–1	1	Reference	1	Reference	1	Reference
2–3	1.22	1.16–1.28	1.15	1.10–1.21	1.14	1.09–1.20
Sleep efficiency						
0–1	1	Reference	1	Reference	1	Reference
2–3	1.07	0.87–1.33	1.04	0.84–1.29	1.01	0.81–1.26
Sleep disturbance						
0–1	1	Reference	1	Reference	1	Reference
2–3	1.47	1.32–1.64	1.43	1.28–1.59	1.30	1.16–1.46
Use of sleeping medication						
0–1	1	Reference	1	Reference	1	Reference
2–3	1.06	0.88–1.27	1.02	0.85–1.23	0.94	0.78–1.13
Daytime dysfunction						
0–1	1	Reference	1	Reference	1	Reference
2–3	1.32	1.18–1.48	1.31	1.17–1.47	1.21	1.08–1.13

Notes: Model 1 was adjusted for sex, age, and body mass index; Model 2 was adjusted for Model 1 variables and socioeconomic variables (residence area, education level, marital status, employment status, and household income); Model 3 was adjusted for Model 2 variables and physical health-related variables (risky drinking, smoking, regular exercise, hypertension, and diabetes mellitus) and mental health-related variables (perceived status of health, perceived level of stress, subjective cognitive decline, and depression).

Abbreviations: CI, confidence interval; OR, odds ratio; PSQI, Pittsburgh Sleep Quality Index.

Interestingly, a meta-analysis of epidemiological and observational studies suggested that not only short sleep duration but also long sleep duration may lead to an increased falls in the adult population.⁵² The incongruent results across the studies might be partly ascribed to differences in potential confounders incorporated in the statistics, including socioeconomic variables, comorbid psychiatric and medical disorders, and the use of psychotropic and hypnotic medications. Indeed, a variety of conditions have been linked to the risk of falls and injuries in the older adult population, including dementia, Parkinson's disease, stroke, depression, diabetes mellitus, rheumatic diseases, pain disorders, dizziness/vertigo, vision impairment, and the use of sedatives and antiepileptic drugs.⁴⁰ Given a high probability of the aforementioned conditions

occurring in older adults, it is bewildering to decide whether short sleep duration per se acts as an independent factor associated with the risk of falls. This association could be more clearly demonstrated by using an adolescent population, since they are in overall good health, and therefore presumed to be free from the conditions that potentially increase the incident falls in the older adult population.^{20–22} Adolescent athletes who slept <8 h per night reported a 1.7-fold higher risk of sports injuries than those sleeping ≥8 h on average.²⁰ In a recent population-based study using a large sample size (57,255 adolescents aged 12–18 years), short sleep duration (≤6 h) was associated with an increased risk of falls, whereas long sleep duration (≥9 h) and longer weekend catch-up sleep contributed to a decreased risk of falls.²² This study strongly

Table 4 Results of Subgroup Analyses by Age Showing Associations Between the PSQI Scores and the Risk of Falls

	Young Adult (n = 48,466)		Middle-Aged Adult (n = 75,737)		Older Adult (n = 77,497)		p-value
Age (range, y)	30.1 ± 6.2 (19–39)		50.2 ± 5.8 (40–59)		70.5 ± 7.5 (≥ 60)		<0.001
Male/female	23,148/25,318		35,032/40,705		35,787/41,710		<0.001
Fallers	397 (0.8)		700 (0.9)		1402 (1.8)		<0.001
PSQI global score	4.4 ± 2.7		4.5 ± 2.7		5.2 ± 3.1		
Good sleep (PSQI ≤5)	35,486 (73.2)		55,575 (73.4)		50,043 (64.6)		<0.001
Poor sleep (PSQI >5)	12,980 (26.8)		20,162 (26.6)		27,454 (35.4)		<0.001
	OR	95% CI	OR	95% CI	OR	95% CI	
Model 1							
Good sleep (PSQI ≤5)	I	Reference	I	Reference	I	Reference	
Poor sleep (PSQI >5)	1.42	1.15–1.75	1.76	1.51–2.05	1.54	1.39–1.72	
Model 2							
Good sleep (PSQI ≤5)	I	Reference	I	Reference	I	Reference	
Poor sleep (PSQI >5)	1.36	1.10–1.67	1.64	1.41–1.92	1.49	1.34–1.66	
Model 3							
Good sleep (PSQI ≤5)	I	Reference	I	Reference	I	Reference	
Poor sleep (PSQI >5)	1.29	1.03–1.61	1.44	1.22–1.71	1.26	1.13–1.42	

Notes: Data are presented as number (percent) or mean ± standard deviation. Group comparisons were made using one-way ANOVA or chi-square test, where appropriate; Model 1 was adjusted for sex, age, and body mass index; Model 2 was adjusted for Model 1 variables and socioeconomic variables (residence area, education level, marital status, employment status, and household income); Model 3 was adjusted for Model 2 variables and physical health-related variables (risky drinking, smoking, regular exercise, hypertension, and diabetes mellitus) and mental health-related variables (perceived status of health, perceived level of stress, subjective cognitive decline, and depression).

Abbreviations: CI, confidence interval; OR, odds ratio; PSQI, Pittsburgh Sleep Quality Index.

suggests that insufficient sleep is a key risk factor for falls, and that long sleep duration as well as weekend catch-up sleep exerts a protecting influence against falls.²² In our fully adjusted model using the seven PSQI components, short sleep duration (OR 1.14, CI 1.09–1.20) independently contributed to an increased risk of falls. Collectively, our results accord well with those of previous studies, pointing to the deleterious effect of short sleep duration on the risk of falls in adult populations.

The possible link between the risk of falls and sleep quality variables other than sleep duration has not been sufficiently studied. To our knowledge, there is one publicly available study that investigated the relationship between incident falls in older men and sleep disturbances using both objective (actigraphy) and subjective sleep measurements (PSQI and Epworth Sleepiness Scale).⁵³ In multivariable-adjusted models, participants who reported excessive daytime sleepiness (Epworth Sleepiness Scale score >10) and slept ≤5 h as per actigraphic measurement were significantly associated with greater odds of experiencing recurrent falls than were their counterparts. The associations between recurrent falls and poor sleep quality (PSQI score >5) and self-reported short sleep time (<5 h)

were also significant after minimal adjustment, but were no longer significant after further adjustment for multiple confounders.⁵³ In our study analyzing individual PSQI components, the risk of falls was associated with short sleep duration (<6 h), increased sleep disturbances (ie, difficulty falling asleep, sleep fragmentation, nocturia, sleep-disordered breathing, cold/hot feelings, bad dreams, and pain), and increased daytime dysfunctions (ie, excessive daytime sleepiness and difficulty concentrating), in line with the previous study findings.⁵³ Taken together, the increased risk of falls could be linked not only to insufficient sleep due to short sleep duration, but also to increased sleep disturbances and daytime dysfunctions.

Although not thoroughly elucidated, plausible mechanisms linking poor sleep quality to falls have been proposed in prior studies. First, consequences of poor sleep quality including impaired daytime functioning, excessive daytime sleepiness, poor cognitive performance, and depressive symptoms have been reported to increase the incident falls and fall-related injuries.^{24,54–56} Second, sleep deprivation and fragmentation due to sleep disturbances cause poor physical functioning and balance/posture control,^{57–60} eventually leading to an increased incidence of falls in sleep-deprived

persons. In addition, reductions in sleep duration and quality might be related to sarcopenia,⁶¹ a potential risk factor for injuries and falls, especially in older adults.^{62,63} Third, poor sleep quality and short sleep duration were related with increased cerebral white matter hyperintensities and stroke in older adults,^{64–66} which was established as a robust risk factor for incident falls.⁶⁷ Last, short sleep duration may provoke a proinflammatory state by increasing levels of inflammatory cytokines including tumor necrosis factor alpha and interleukin-6.^{68,69} This chronic inflammatory condition could cause diminished muscle mass and strength as well as reduced gait speed, leading to an increased incidence of falls.^{70,71}

The strengths of this study may be the use of a population-based, large-sample dataset and the adoption of a sampling process representative of the general population. Furthermore, this survey offered information regarding a number of confounders related with falls, which allowed us to explore the independent effect of poor sleep quality on the risk of falls using multiple statistical adjustments. Our results need to be interpreted within the confines of at least five potential limitations. First, the causality between poor sleep quality and the risk of falls could not be established due to the cross-sectional design in this survey. Second, because all data were entirely collected via self-administered questionnaires, recall bias leading to the probability of under- or over-reporting cannot be totally excluded. Furthermore, subjective measures for sleep (ie, PSQI scores) have shown weak or inconsistent correlations with objective measures (ie, actigraphy and polysomnography);^{72–74} thus, future studies adopting both types of sleep measures are required to corroborate our findings. Third, although the PSQI cut-off score of 5 is the most widely used in sleep medicine, there has been some debate as to whether this cutoff score could be an optimal threshold indicating good or poor sleep quality. Some authors suggested a higher threshold to substantially differentiate good sleepers from poor sleepers.^{75,76} Moreover, a recent study found a discrepancy between the PSQI scores on work-free days and workdays, suggesting the influences of chronotype and social jetlag on sleep quality.⁷⁷ Fourth, dichotomous question for history of falls may limit assessment of clinical significance of falls such as place and number of falls, severity of falls, and associated morbidity. Moreover, sleep quality measured during the past one month is insufficient to be analyzed to assess the risk of falls that occurred during the past 12 months. Last, we did not

investigate the use of fall risk-increasing drugs, such as analgesics, psychotropic drugs (antipsychotics, anxiolytics, antidepressants), cardiovascular drugs, and polypharmacy,^{78–80} which might affect the results.

Conclusions

Sleep deprivation has been strongly linked to falls, a leading cause of morbidity and mortality particularly in the older adult population. Our nationwide population-based study using the PSQI corroborates the previous finding that poor sleep quality caused by short sleep duration is a major risk factor of falls in adult populations. Furthermore, our findings imply that increased sleep disturbances and daytime dysfunctions independently contribute to the risk of falls. Our results have clinical and public health perspectives that increasing sleep duration and reducing daytime dysfunctions and sleep disturbances could mitigate unintentional falls and fall-related injuries. Further prospective longitudinal studies using both objective and subjective assessments of sleep quality on a large scale are required to confirm the detrimental influence of poor sleep quality on the risk of falls.

Abbreviations

PHQ-9, patient health questionnaire-9; PSQI, Pittsburgh sleep quality index; SCD, subjective cognitive decline.

Data Sharing Statement

The dataset used and analyzed in the current study is available from the corresponding author on reasonable request. Raw data are available on the Korea Community Health Survey website (<https://chs.kdca.go.kr/chs/index.do>).

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Disclosure

All authors declare no potential conflicts of interest.

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