

**Association between subjective sleep quality and future risk of falls in older people:
results from LOHAS**

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Abstract

Background: Inadequate sleep is correlated with morbidity and mortality among older adults. However, the longitudinal relationship between subjective sleep quality and risk of falls in the elderly remains to be clarified.

Methods: Study participants were from Locomotive Syndrome and Health Outcome in Aizu Cohort Study (LOHAS) sites (1071 community-dwelling people ≥ 65 years of age, mean, 71 years). Subjective sleep quality was measured by the Pittsburgh Sleep Quality Index (PSQI). Occurrence of falls (defined as experiencing at least one fall) during the subsequent year was ascertained by a self-reported questionnaire.

Results: Mean global PSQI score was 4.3 (standard deviation, 3.2), with 28.9% of participants rating their sleep quality as poor (PSQI >5). A total of 210 participants (19.6%) fell at least once in the year following sleep examination. Multivariable analysis revealed that participants reporting worse subjective sleep quality had significantly higher odds of experiencing falls during the one-year follow-up period (adjusted odds ratio (AOR)=1.50 for each three point increase in global PSQI score; 95% confidence interval (CI)=1.20, 1.89). Participants in the highest global PSQI score (PSQI >5) quartile had significantly increased odds of experiencing falls compared to those in the lowest global score quartile (PSQI <2 ; AOR=2.14; 95% CI=1.09, 4.22). This association was similarly significant in subgroup analyses for older men and women, non-users of sleep medication, and those without a history of falls at baseline.

Conclusion: Subjective poor sleep quality, as measured by the PSQI, is longitudinally associated with greater risk of experiencing falls in community-dwelling older adults.

Keywords: falls, sleep, primary care, cohort study

Introduction

Falls in the elderly are frequent and can have serious implications. Approximately one-third of people aged 65 and over experience falls each year (1). Falls can result in mild to severe injuries, including visits to the emergency department (2). Consequently, fall-related injuries such as hip fractures and traumatic brain injuries are associated with morbidity and mortality (3-6). Given that the aged population continues both to grow in number and live for longer, the number of falls and associated medical costs are likewise expected to increase (3,6). Moreover, for those who do not incur injuries from falls, the experience of the fall itself can reduce self-confidence and lead to restrictions, imposed not only by themselves but also by family members, on the breadth of daily activities, which can result in a decline of physical function (4-7). Falls therefore impose a tremendous burden on the healthcare system (4-6, 8).

Falls in the elderly have been linked to self-reported sleep problems (9-14). Sleep problems can cause falls through effects on balance and cognition (15-17). Falls can also result from the side effects of medications used to treat sleep problems or other medical conditions (4-6, 8). It is clear that good sleep quality is associated with general health and longevity (18). Interestingly, however, nearly half of the population of older adults complain of sleep problems, with inadequate sleep being significantly correlated with morbidity and mortality among older adults (19).

Most studies that have reported associations between self-reported sleep problems and falls in the elderly were conducted using a cross-sectional design, and their results remain controversial (9-13). Furthermore, very few studies have demonstrated the relationship between sleep duration and efficiency, and subsequent risk of falls (14, 20). These studies assessed sleep duration and efficiency using actigraphy, which has limitations for the

measurement of some sleep parameters, including sleep-wake status and the reliability (reproducibility) of individual habitual sleep patterns (14, 20, 21). Moreover, objectively measured sleep parameters do not necessarily reflect individuals' subjective sleep complaints, nor do they detect insomnia, whose clinical diagnosis relies on subjective perception of sleep difficulty (22). Furthermore, actigraphy use is difficult to incorporate into primary-care settings, including family clinics and annual health checks (21). Therefore, the relationship between sleep quality and risk of falls in the elderly remains to be clarified.

The Pittsburgh Sleep Quality Index (PSQI) is an alternative method to assess sleep quality. It is a reliable and psychometrically validated self-rated questionnaire for the assessment of subjective sleep quality over a one-month time period (23, 24). Although the association between subjective sleep quality as measured by the PSQI and risk of falls has been studied in older men (14), it remains unclear whether it holds true for older women and the general elderly population.

Here, we examined the association between subjective sleep quality as measured by the PSQI and subsequent risk of falls using data from a large cohort of community dwelling older adults in the Locomotive Syndrome and Health Outcome in Aizu cohort study (LOHAS).

Methods

Participants

The LOHAS is an ongoing prospective cohort study originally designed to estimate the risk of cardiovascular disease, quality of life, medical costs, and mortality ascribed to locomotor dysfunction (25). The study recruited community-dwelling individuals aged 40 to 80 years in the towns of Minami-Aizu and Tadami in Fukushima Prefecture, Japan, who were enrolled in

a National Health Insurance plan and who participated in annual health checks conducted by their local governments (2008-2010) (25). The baseline survey included self-administered questionnaires, health checks, biochemical measurements, musculoskeletal examinations, and motor dysfunction and radiographic assessments. Further details of the LOHAS have been published elsewhere (25). The present study enrolled subjects from the LOHAS baseline survey. All participants provided written informed consent to participate, and the study was approved by the institutional review boards of Fukushima Medical University School of Medicine and Kyoto University School of Medicine. Only data from participants aged 65 and over who received health checks for two consecutive years in 2008 and 2009 were analyzed.

Assessment of sleep

Subjective sleep quality was assessed using the Japanese version of the PSQI in the first year of examination (2008). In the PSQI questionnaire, nineteen self-rated questions generate seven component scores (on a scale of 0 to 3, with higher scores indicating poorer sleep quality): C1, sleep quality; C2, sleep latency; C3, sleep duration; C4, sleep efficiency; C5, sleep disturbances; C6, use of sleep medication; C7, daytime dysfunction. These seven scores are summed to yield a global score. Global PSQI scores range from 0 to 21, with those >5 used to indicate poor sleep quality (23, 24).

Assessment of falls

We assessed the outcome of ‘any falls’ in the year following the sleep assessment using a self-administered questionnaire, which was distributed before, and collected on the day of the next consecutive health check in the second year (2009). Information on falls was obtained using the question: ‘Over the past year, have you fallen down?’ Participants who answered ‘yes’ were considered to have had ‘any fall’. The baseline information on falls was collected

in the same way at the beginning of the first year.

Measurement of potential confounding variables

Sociodemographic variables (age, gender, whether the participants lived alone ('live-alone') or with families), health-related behaviors (physical activity, consumption of alcohol), physical function, and selected medical information (cerebrovascular, cardiovascular, and chronic pulmonary diseases; diabetes mellitus (DM); hypertension (HTN); use of sleep medication) were obtained by a self-reported questionnaire. Physical activity was evaluated using the Japanese version of the International Physical Activity Questionnaire (IPAQ) and classified into inactive and active, as previously described (26). Physical function was assessed by the Medical Outcome Study Short-Form 36-Item Health Survey (SF-36) physical functioning (PF) domain scores, which range from 0 to 100, with higher numbers indicating better physical function (27, 28), a score of <50 was used to define functional disability. Depressive symptoms were identified using the Mental Health Inventory (MHI-5), a five-question subscale of the SF-36 questionnaire (29); participants with a MHI-5 score of ≤ 60 were considered to have depressive symptoms.

Statistical analysis

Characteristics of participants were summarized as counts and percentages for categorical variables, and as mean and standard deviation (SD) or median and interquartile range for continuous variables. The association between sleep quality and risk of falls was examined using logistic regression analyses (unadjusted, age- and gender-adjusted, minimally-adjusted, and multivariable-adjusted models). Results were presented as odds ratios (ORs) with 95% confidence intervals (CIs). Minimally-adjusted models were adjusted for age, gender and any falls in the previous year. Additional potential confounding variables (body mass index (BMI),

medical condition (cerebrovascular, cardiovascular, and chronic pulmonary diseases; DM; and HTN), physical activity, depression, use of sleep medication, alcohol consumption, physical function, and live-alone) were included in a multivariable-adjusted model.

In each model, sleep quality was assessed using the PSQI. In our primary analysis, we examined the association between continuous global PSQI scores (in three-point increments) and falls. A three-point change in global PSQI scores was used to indicate a minimal clinically important difference (MCID) based on previous studies (30). In our secondary analysis, the global PSQI scores were categorized by quartile. Each model contained quartiles of global PSQI scores as the primary predictor. The reference quartile comprised the lowest PSQI scores. We conducted primary and secondary analyses for complete cases, excluding missing values in covariates.

To examine the association between each PSQI component and falls, exploratory analyses were conducted. First, component scores (0-3) were expressed as ordinal categorical variables and the relationship between PSQI components and falls was determined using the chi-square statistic for trend to investigate any dose-response relationship. Second, component scores were expressed as dichotomous variables (“none” (0) and “any symptoms” (1-3)) to examine the association using logistic regression analyses. The methods are described in full in the supplementary materials.

Subgroup analyses were performed as follows: (1) according to gender to investigate the homogeneity of the exposure’s (subjective poor sleep quality) effect on the fall outcome (6, 10, 14); and (2) limited to participants not using sleep medication at baseline to reduce the confounding effects of hypnotic medications.

The robustness of the main results was ascertained using two sensitivity analyses. One was conducted using a restricted definition of ‘at-risk population’, such that only those without previous falls at baseline were included in the analysis, since a history of falls could affect the outcome. In the second, missing values in covariates were handled with multiple imputations (MI); covariates related to missing data were included in the imputations and the multivariable-adjusted model to generate twenty data sets. All statistical values were obtained from two-sided analyses. All analyses were conducted using STATA version 13.1 software (STATA Corporation, College Station, TX).

Results

Of the 1685 participants who completed the PSQI questionnaire (Supplementary Table S1), 1071 participants satisfied the study criteria (Supplementary Figure S1). The average age (SD) of the analysis cohort was 71.1 (4.4) years, and 58.9% were female. The mean global PSQI score (SD) was 4.3 (3.2), with 28.9% rating their sleep quality as poor. Baseline characteristics of the study participants and by categories of sleep quality are shown in Table 1. A total of 210 participants (19.6%) experienced at least one fall in the year after the sleep examination. Moreover, 17.6% of participants with good sleep quality reported at least one fall, compared with 24.5% of those with poor sleep quality.

Association between global PSQI score and occurrence of any falls

In our primary analysis, worse sleep quality (increase in global PSQI score) was significantly associated with greater risk of falls in all four models (Table 2). In the multivariable-adjusted model, the adjusted odds ratio (AOR) of experiencing any falls during the one-year follow-up period was 1.50 (95% CI=1.20, 1.89) for each three-point increase in global PSQI score.

In our secondary analysis, when continuous global PSQI score was categorized into quartiles, the highest global PSQI score was significantly associated with an increased risk of falls compared to the lowest global score in all four models (Table 2). Similarly, in the multivariable-adjusted model, participants in the highest global PSQI score quartile showed significantly increased odds of experiencing falls compared to those in the lowest quartile of global scores (AOR=2.14; 95% CI=1.09, 4.22).

Association between each PSQI component and occurrence of any falls

In our exploratory analysis, falls were increasingly observed across scores for C1: sleep quality (p for trend <0.001), C4: sleep efficiency (p for trend =0.001), C5: sleep disturbances (p for trend <0.001) and C7: daytime dysfunction (p for trend <0.001; Figure 1). The proportion of those experiencing any falls during the one-year follow-up period was lower among those with lower scores, and higher among those with higher scores for these components. In contrast, there was no association between C2: sleep latency and C6: use of sleep medication, and risk of falls. When component scores were dichotomized into categories of “none” (0) and “any symptoms” (1-3), C4, C5 and C7 were significantly associated with increased odds of experiencing falls (Supplementary Table S3). The full results are presented in the supplementary materials.

Subgroup analysis

1. By gender (men or women)

The odds ratios for the association between global PSQI score and the risk of any falls in older men and women are shown in Supplementary Table S2. Worse sleep quality was significantly associated with increased risk of falls for both men and women. In the

multivariable-adjusted model, the odds ratios for experiencing falls during the one-year follow-up period for men and women were 1.52 (95% CI=1.05, 2.22) and 1.47 (95% CI=1.09, 1.98) for each three point increase in global PSQI score, respectively.

2. Nonusers of sleep medication

Among nonusers of sleep medication, worse sleep quality was significantly associated with increased risk of falls (Supplementary Table S2). In the multivariable-adjusted model, the odds ratio for experiencing falls during the one-year follow-up period was 1.54 (95% CI=1.15, 2.06) for each three point increase in global PSQI score.

Sensitivity analysis

Under the restricted definition of ‘at-risk population’ among non-fallers at baseline, worse sleep quality was significantly associated with increased risk of falls (Supplementary Table S2). In the multivariable-adjusted model, the odds ratio for experiencing falls during the one-year follow-up period was 1.42 (95% CI=1.07, 1.88) for each three point increase in global PSQI score.

Although multiple imputations analysis of the entire cohort showed that the effect of poor sleep quality on falls was reduced, the association remained significant (AOR=1.40; 95% CI=1.15, 1.70). The results were similar in men (AOR=1.44; 95% CI=1.05, 2.01) and women (AOR=1.38; 95% CI=1.08, 1.78). This association remained significant even among non-fallers (AOR=1.29; 95% CI=1.01, 1.63).

Discussion

We showed that self-reported poor sleep quality as measured by the PSQI was associated

with a high risk of falls among community-dwelling older adults. Subgroup analyses classified by gender showed that both men and women with subjective poor sleep quality were at similarly increased risk of experiencing falls. Likewise, when current users of sleep medication were excluded from the analyses, poor sleep quality was associated with falls. The robustness of our results was ascertained by our sensitivity analysis: limiting our analysis to non-fallers at baseline attenuated the strength of the association between poor sleep quality and risk of falling, but the association remained significant.

To our knowledge, this is the first study to demonstrate the relationship between subjective sleep quality as measured by the PSQI and the risk of falls in both older males and females. Previous studies examining the association between self-reported sleep problems and risk of falls among community-based older adults were primarily cross-sectional studies with a number of important limitations, such as use of unvalidated self-reported questionnaires to assess sleep habits and insufficient adjustment for potential confounders, including use of hypnotic medications and a history of falls (which is a known strong confounder; Table 2) (9-14, 20). In the present study, we adjusted for potential confounders, including current use of sleep medication, and simultaneously controlled for fall history. Therefore, we show a strong and robust correlation between subjective poor sleep quality and risk of falls in both older men and women.

Our results agree with a report by Stone et al., who showed that subjective poor sleep quality as measured by the PSQI was significantly associated with recurrent falls in the year following sleep assessment in community-dwelling older men, after minimal adjustment (14). However, this association was no longer significant after multivariable adjustment (14). This suggests that subjective poor sleep quality may be more strongly associated with the risk of

falling in general, than of recurrent falls (4, 6, 7, 31, 32).

We also identified an association between individual PSQI components of subjective sleep quality and falls. Component scores for sleep efficiency, sleep disturbances and daytime dysfunction were significantly associated with the incidence of falls. Moreover, the shortest sleep duration (<5 hours) was highly associated with falls, supporting previous findings (10, 12, 14, 20). Surprisingly, unlike other studies in this area, we did not observe an association between the use of sleep medication and falls. The reason for this discrepancy is not clear, although there may have been some biases in our study that led to an underestimation of such an association; for example, we could not evaluate the proportion of fallers among those who were lost to follow-up. Nevertheless, our results are in agreement with studies suggesting that poor sleep may play a part in mediating the relationship between the use of hypnotics and risk of falls in older adults (20). Specific focus on independent associations between the PSQI components and falls may enhance the efficiency of evaluations and lead to more appropriate and effective interventions to prevent falls in high-risk populations. In particular, our results suggest that sleep disturbances might be a key component; however, further studies are needed to confirm the existence of an association between individual PSQI components and risk of falls.

A variety of mechanisms may explain the association between poor sleep quality and risk of falls. Short sleep time and low sleep efficiency may result primarily from sleep disturbances, and correspond to sleep deprivation and fragmentation. This can lead to a decline in daytime function, impairing psychomotor performance and cognitive function (15, 16). A study by Schlesinger et al. examining the effect of sleep deprivation on postural sway suggests that sleep deprivation impairs a person's ability to maintain standing postural balance under

conditions of high information-processing demand, such as when completing a difficult cognitive task or exerting high levels of concentration (17). Therefore, sleep disturbances reduce attention for postural control, which would likely greatly affect the elderly population as balancing becomes more difficult with age (33), causing them to stumble, trip, and fall. Furthermore, sleep disturbances may act as a gateway to factors that increase the risk of sarcopenia and frailty, which can lead to falls (34, 35). Accordingly, a recent study revealed that poor subjective sleep quality is a risk factor for the development of frailty and mortality in older men (36). Since falls are also a risk factor for morbidity and mortality, future studies should examine the details of fall outcomes, such as severity, hospitalization and impact on the healthcare system, in association with subjective sleep quality using population-based large-scale analysis of both older men and women.

Our findings indicate a robust association between subjective poor sleep quality and subsequent falls in both older men and women. Even in non-fallers, the association was still observed, suggesting that an effect-cause association is unlikely. Strong evidence indicates that poor sleep quality can affect fall risk. However, the possibility of bidirectionality remains: given that older people have been shown to exhibit persistent psychological problems such as anxiety, depression and posttraumatic stress disorder following falls, falls may also cause poor sleep (37, 38).

Strengths of this study include the use of a large sample size of community-dwelling older adults, including both men and women, in a longitudinal study design. We also used the validated PSQI questionnaire to assess subjective sleep quality. There were also some limitations. First, information on sleep and falls was obtained by self-administered questionnaires, which may be subject to misclassification for the falls outcome and rating of

sleep quality. However, such questionnaires are meaningful for assessing subjects' subjective sleep quality. Reporting bias may be possible if subjects with poor sleep quality underreported falls. Second, due to limited data, we could not account for potentially important confounders in our analysis, including cognitive function, lower urinary tract symptoms, Parkinson's disease, cancer and use of other specific medications. Third, although a multiple imputation method was used for missing data based on the assumption of "missing at random", the exact reasons underlying the missing data are unknown. Furthermore, there was little information on data lost to follow-up. Finally, our results may not be generalizable to other populations, such as those of other ethnicities.

In conclusion, we found that subjective poor sleep quality as measured by the PSQI was longitudinally associated with greater risk of falls among community-dwelling older men and women. Further studies into the association between individual PSQI components and risk of falls may allow for the development of effective interventions to prevent falls in high-risk populations.

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Table 1. Characteristics of Participants by Categories of Global PSQI Score

Characteristic	All Participants (N=1071)	Pittsburgh Sleep Quality Index	
		≤5 (N=761)	>5 (N=310)
Age y, mean (SD),	71.1 (4.4)	71.0 (4.2)	71.3 (4.6)
Female, %	58.9	55.3	67.7
BMI ≥25 kg/m ² , %	31.9	31.5	32.8
Global PSQI score range 0-21, mean (SD)	4.3 (3.2)	2.7 (1.5)	8.4 (2.5)
IPAQ inactive, %	16.0	16.1	15.7
SF-36 PF ≤50, %	8.3	7.1	11.1
Depression MHI-5 score ≤60, %	23.9	19.6	34.6
Current sleep medication use ≥1/week, %	16.4	2.8	50.0
Alcohol consumption everyday or sometimes, %	41.1	42.7	36.8
Live-alone, %	8.9	7.3	12.8
Comorbid conditions, %			
Cerebrovascular disease ^a	5.5	4.7	7.6
Cardiovascular disease ^b	7.7	7.5	8.3
Chronic pulmonary disease ^c	5.5	5.0	6.8
Diabetes under treatment with oral antidiabetic drugs or insulin	4.1	4.1	4.0
Hypertension under treatment with antihypertensive drugs	45.5	44.0	49.3

Any falls in the previous year ^d , %	18.9	17.5	22.5
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Notes: SD = standard deviation; BMI = body mass index; PSQI = Pittsburgh Sleep Quality Index; IPAQ = International Physical Activity Questionnaire; SF-36 PF = Medical Outcome Study Short-Form 36-Item Health Survey physical functioning domain scores; MHI = mental health inventory.

^aCerebrovascular disease includes stroke, cerebral hemorrhage, etc.

^bCardiovascular disease includes angina, myocardial infarction, etc.

^cChronic pulmonary disease includes bronchial asthma, chronic obstructive pulmonary disease, pulmonary fibrosis, lung cancer, etc.

^dAny falls is defined as at least one fall experienced in the one-year follow-up period.

Table 2. Global PSQI Score and Risk of any Falls during the One-year Follow-up Period

Expression of predictor variable Unit/Category	Any Falls ^a Unadjusted		Age & Gender- adjusted	Minimally- adjusted ^b	Multivariable- adjusted ^c
	N=1071	N=1071	N=1071	N=1043	N=807
	N (%)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Continuous variable					
3 point increase	210 (19.6)	1.32 (1.16, 1.51)	1.33 (1.16, 1.52)	1.29 (1.11, 1.50)	1.50 (1.20, 1.89)
Quartiles					
Quartile 1, PSQI=0-1 (N=189)	26 (13.8)	1 (Reference)	1 (Reference)	1 (Reference)	1 (Reference)
Quartile 2, PSQI=2-3 (N=316)	58 (18.4)	1.41 (0.85, 2.32)	1.43 (0.86, 2.37)	1.18 (0.69, 2.02)	1.29 (0.69, 2.41)
Quartile 3, PSQI=4-5 (N=256)	50 (19.5)	1.52 (0.91, 2.55)	1.55 (0.92, 2.61)	1.27 (0.73, 2.21)	1.38 (0.72, 2.65)
Quartile 4, PSQI=6-21 (N=310)	76 (24.5)	2.04 (1.25, 3.32)	2.04 (1.24, 3.34)	1.77 (1.05, 3.00)	2.14 (1.09, 4.22)

Notes: PSQI = Pittsburgh Sleep Quality Index; OR = Odds ratio; CI = Confidence Interval.

^aAny falls is defined as at least one fall experienced in the one-year follow-up period.

^bAdjusted for age, gender and any falls in the previous year.

^cAdjusted for age, gender, any falls in the previous year, body mass index, alcohol consumption, live-alone, physical activity, physical function, sleep medication use, depression, cerebrovascular disease, cardiovascular disease, chronic pulmonary disease, diabetes mellitus and hypertension.

Figure 1. Association Between Seven PSQI Component Scores and Proportion of Participants Reporting any Falls^a during a One-year Follow-up Period

Notes: PSQI = Pittsburgh Sleep Quality Index.

^aAny falls is defined as at least one fall experienced in the one-year follow-up period.

*P-value for trend <0.01

**P-value for trend <0.001

Supplementary Materials

1. Supplementary methods

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Association between each PSQI component and occurrence of any falls (“none” versus “any symptoms”)

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Characteristics of Participants who were or were not Lost to Follow-up

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PSQI Component Score and Risk of any Falls during a One-year Follow-up

Supplementary Figure S1

Flow Chart of Participants Through the Study

1. Supplementary methods

Statistical analysis

Exploratory analyses

To examine the association between each PSQI component and falls, additional analyses were conducted. Component scores were expressed as dichotomous variables. Each component score was dichotomized into categories of “none” (0) and “any symptoms” (1-3). The association between each PSQI component and risk of falls was examined using logistic regression analyses (unadjusted, minimally-adjusted, and multivariable-adjusted models) in the same way as for the primary and secondary analyses. In each model, dichotomized PSQI component variables were regarded as distinct primary predictors. Results were presented as odds ratios (ORs) with 95% confidence intervals (CIs). We conducted exploratory analyses for complete cases, excluding missing values in covariates.

2. Supplementary results

Exploratory analyses

Association between each PSQI component and occurrence of any falls (“none” versus “any symptoms”)

When each PSQI component score was dichotomized into “none” (0) and “any symptoms” (1-3), higher component scores (1-3) for C4: sleep efficiency, C5: sleep disturbances and C7: daytime dysfunction were each significantly associated with an increased risk of falls compared to the lowest component score of zero (Supplementary Table S3). In the multivariable-adjusted model, participants with C4: poor sleep efficiency (AOR=1.68; 95% CI=1.08, 2.61), C5: sleep disturbances (AOR=1.89; 95% CI=1.21, 2.97) and C7: daytime dysfunction (AOR=1.58; 95% CI=1.07, 2.35) each showed significantly increased odds of experiencing falls compared to those without these symptoms.

3. Supplementary tables and figures

Supplementary Table S1. Characteristics of Participants who were or were not Lost to Follow-up

Characteristic	All Participants (N=1071)	Lost to Follow-up (N=614)
Age y, mean (SD)	71.1 (4.4)	74.9 (6.0)
Female, %	58.9	54.2
BMI ≥ 25 , %	31.9	34.1
Global PSQI score range 0-21, mean (SD)	4.3 (3.2)	4.4 (3.2)
IPAQ inactive, %	16.0	21.7
SF-36 PF ≤ 50 , %	8.3	19.0
Depression MH-5 score ≤ 60 , %	23.9	21.9
Current sleep medication use ≥ 1 /week, %	16.4	21.0
Alcohol consumption everyday or sometimes, %	41.1	36.4
Live-alone, %	8.9	12.0
Comorbid conditions, %		
Cerebrovascular disease ^a	5.5	5.9
Cardiovascular disease ^b	7.7	12.3
Chronic pulmonary disease ^c	5.5	4.9
Diabetes under treatment with oral antidiabetic drugs or insulin	4.1	6.9
Hypertension under treatment with antihypertensive drugs	45.5	51.3
Any falls in the previous year ^d , %	18.9	19.5

Notes: SD = standard deviation; BMI = body mass index; PSQI = Pittsburgh Sleep Quality Index; IPAQ = International Physical Activity Questionnaire; SF-36 PF = Medical Outcome Study Short-Form 36-Item Health Survey physical functioning domain scores; MHI = mental health inventory.

^aCerebrovascular disease includes stroke, cerebral hemorrhage, etc.

^bCardiovascular disease includes angina, myocardial infarction, etc.

^cChronic pulmonary disease includes bronchial asthma, chronic obstructive pulmonary disease, pulmonary fibrosis, lung cancer, etc.

^dAny falls is defined as at least one fall experienced in the one-year follow-up period.

Supplementary Table S2. Continuous Global PSQI Score and Risk of any Falls during a One-year Follow-up for Older Men, Women, Nonusers of Sleep Medication and Non-fallers at Baseline, for each Three-point Increase

	Participants	Any Falls ^a	Multivariable-adjusted ^b	Multiple Imputations
Subgroup	N	N (%)	OR (95% CI)	OR (95% CI)
Older Men	440	83 (18.9)	1.52 (1.05, 2.22)	1.44 (1.05, 2.01)
Older Women	631	127 (20.1)	1.47 (1.09, 1.98)	1.38 (1.08, 1.78)
Nonusers of Sleep Medication	856	158 (18.5)	1.54 (1.15, 2.06)	1.43 (1.12, 1.84)
Non-fallers at Baseline	846	109 (12.9)	1.42 (1.07, 1.88)	1.29 (1.01, 1.63)

Notes: PSQI = Pittsburgh Sleep Quality Index; OR=Odds Ratio; CI = Confidence Interval. Total N for the multivariable-adjusted model: Older men, 351; Older women, 456; Nonusers of Sleep Medication, 652; Non-fallers at baseline, 665.

^aAny falls is defined as at least one fall experienced in the one-year follow-up period.

^bAdjusted for age, gender, any falls in the previous year, body mass index, alcohol consumption, live-alone, physical activity, physical function, sleep medication use, depression, cerebrovascular disease, cardiovascular disease, chronic pulmonary disease, diabetes mellitus and hypertension. Covariates of gender, sleep medication use and any falls in the previous year were excluded from the models for older men and women, nonusers of sleep medication and non-fallers at baseline, respectively.

Supplementary Table S3. PSQI Component Score and Risk of any Falls during a One-year Follow-up

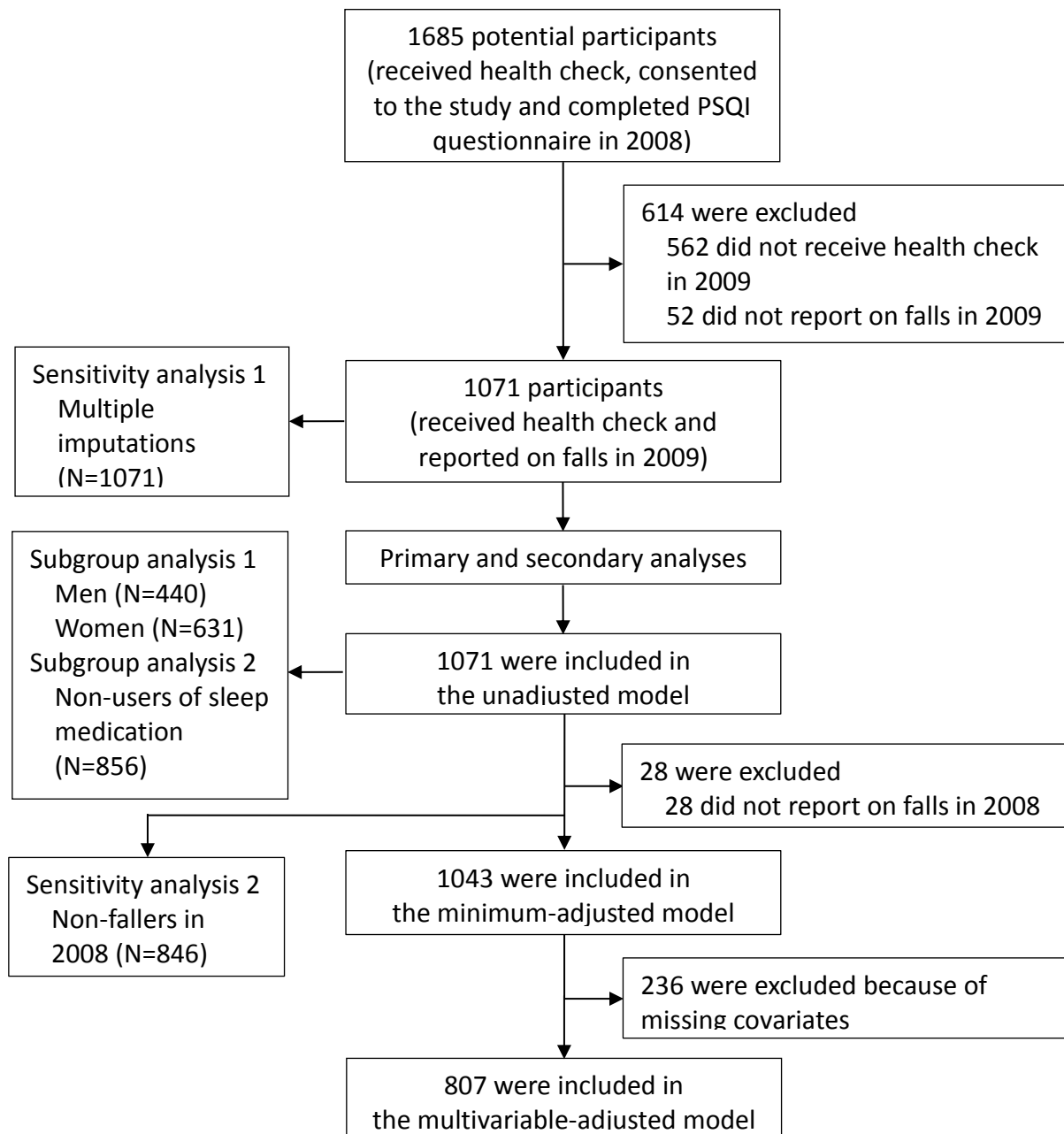
Predictor	Participants	Any Falls^a	Unadjusted	Multivariable-adjusted^b
Component scores	N	N (%)	N=1071	N=807
			OR (95% CI)	OR (95% CI)
C1, sleep quality				
0	351	59 (16.8)	1 (Reference)	1 (Reference)
1-3	720	151 (21.0)	1.31 (0.94, 1.83)	1.28 (0.84, 1.95)
C2, sleep latency				
0	438	82 (18.7)	1 (Reference)	1 (Reference)
1-3	633	128 (20.2)	1.10 (0.81, 1.50)	0.96 (0.64, 1.44)
C3, sleep duration				
0	564	111 (19.7)	1 (Reference)	1 (Reference)
1-3	507	99 (19.5)	0.99 (0.73, 1.34)	1.03 (0.69, 1.53)
C4, sleep efficiency				
0	829	149 (18.0)	1 (Reference)	1 (Reference)
1-3	242	61 (25.2)	1.54 (1.09, 2.16)	1.68 (1.08, 2.61)
C5, sleep disturbances				
0	349	48 (13.8)	1 (Reference)	1 (Reference)
1-3	722	162 (22.4)	1.81 (1.28, 2.58)	1.89 (1.21, 2.97)
C6, use of sleep medication				
0	856	158 (18.5)	1 (Reference)	1 (Reference)
1-3	215	52 (24.2)	1.41 (0.99, 2.01)	1.43 (0.88, 2.31)
C7, daytime dysfunction				
0	660	104 (15.8)	1 (Reference)	1 (Reference)
1-3	411	106 (25.8)	1.86 (1.37, 2.52)	1.58 (1.07, 2.35)

Notes: PSQI = Pittsburgh Sleep Quality Index; OR=Odds Ratio; CI = Confidence Interval; C=Component.

^aAny falls is defined as at least one fall experienced in the one-year follow-up period.

^bAdjusted for age, gender, any falls in the previous year, body mass index, alcohol consumption, live-alone, physical activity, physical function, sleep medication use, depression, cerebrovascular disease, cardiovascular disease, chronic pulmonary disease, diabetes mellitus and hypertension. The sleep medication use covariate was excluded from the analyses for C6 (use of sleep medication).

Supplementary Figure S1. Flow Chart of Participants Through the Study



Notes: PSQI=Pittsburgh Sleep Quality Index.

