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ORIGINAL ARTICLE

Sleep Disturbances and Risk of Hospitalization and Inpatient Days Among Older Women

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Study Objectives: Determine the associations of sleep disturbances with hospitalization risk among older women.

Methods: One thousand eight hundred and twenty-seven women (mean age 83.6 years) participating in Study of Osteoporotic Fractures Year 16 (Y16) examination (2002–2004) linked with Medicare and/or HMO claims. At Y16 examination, sleep/wake parameters were measured by actigraphy (total sleep time [TST], sleep efficiency [SE], sleep latency [SL], and wake after sleep onset [WASO]) and subjective sleep measures (sleep quality [Pittsburgh Sleep Quality Index] and daytime sleepiness [Epworth Sleepiness Scale]) were assessed by questionnaire. Measures except TST were dichotomized based on clinical thresholds. Incident hospitalizations were determined from claims data.

Results: Nine hundred and seventy-six women (53%) had ≥1 hospitalization in the 3 years after the Year 16 examination. Reduced SE (odds ratio [OR] = 2.39, 95% confidence interval [CI] 1.69–3.39), prolonged SL (OR = 1.41, 95% CI 1.11–1.78), greater WASO (OR = 1.57, 95% CI 1.28–1.93), shorter TST (OR = 1.98, 95% CI 1.42–2.77) and poorer sleep quality (OR = 1.33, 95% CI 1.07–1.65) were each associated with a higher age and site-adjusted odds of hospitalization; associations were attenuated after multivariable adjustment for traditional prognostic factors with the OR for reduced SE (OR = 1.60, 95% CI 1.08–2.38) and shorter TST (OR = 1.63, 95% CI 1.12–2.37) remaining significant. Among women who were hospitalized, greater WASO (rate ratio [RR] = 1.20, 95% CI 1.04–1.37) and poorer sleep quality (RR = 1.18, 95% CI 1.02–1.35) were each associated with a greater age and site-adjusted RR of inpatient days, but associations did not persist after multivariate adjustment.

Conclusions: Older women with sleep disturbances have an increased risk of hospitalization partially attributable to demographics, poorer health status, and comorbidities.

Keywords: sleep disturbances, Medicare, hospitalization, aging, sleep quality.

Statement of Significance

Previous studies have reported that sleep disturbances are associated with greater healthcare utilization, but relied on self-reported sleep data and did not focus specifically on older adults. This study used cohort data linked with claims data to determine whether self-reported and objectively measured sleep disturbances are associated with risk of hospitalization in older community-dwelling women. Poorer subjective sleep quality and objectively measured reduced sleep efficiency, prolonged sleep latency, greater nighttime wakefulness, and shorter total sleep time were each associated with a higher hospitalization risk. These associations were explained in part by greater comorbidity burden and poorer health status among women with sleep disruption, but reduced sleep efficiency and shorter total sleep time were independent predictors of hospitalization risk.

INTRODUCTION

Sleep complaints, such as difficulty getting to sleep, fragmented sleep, early morning awakenings and reduced total sleep time (TST) are common in older adults. Prior studies have observed that up to 50% of older adults report having difficulty with at least one of these symptoms,[1,2] which indicates that insufficient sleep is a prevalent health concern among aged populations.

Older age is also associated with an increased risk of hospitalization. In a 2012 Health Care Cost and Utilization Project (HCUP) report, the rate of inpatient admissions for adults aged 65–84 years was 260.9/1000 persons, and 502.0/1000 persons[3] for adults aged 85 and older. According to the Kaiser Family Foundation, inpatient care in 2011 accounted for the greatest portion of spending for Medicare beneficiaries aged 65 and older.[4]

Prior studies[5–7] suggested that sleep disturbances and sleep disorders including insomnia are associated with greater healthcare utilization. These studies have not focused specifically on older adult populations, where the burden of sleep disorders and risk of inpatient hospitalizations are highest, and have also relied on self-reported sleep data that may not be as accurate as more objective sleep measures from actigraphy or polysomnography.

Using data from the Study of Osteoporotic Fractures (SOF; a longitudinal cohort study of older women) linked with inpatient Medicare claims and inpatient Kaiser Permanente encounters, our objective was to determine whether sleep disturbances are independently associated with a subsequent increased risk of all-cause hospitalization and greater rates of inpatient days in community-dwelling older women.

METHODS

Study Population and Linkage to Inpatient Claims

SOF is a longitudinal cohort study designed to examine risk factors for osteoporotic fractures and other age-related conditions. Women were recruited from four US clinical centers (Baltimore,

Maryland; Minneapolis, Minnesota; the Monongahela Valley nears Pittsburgh, Pennsylvania; and Portland, Oregon).[8] At the baseline examination conducted between 1986 and 1988, SOF enrolled 9704 community-dwelling white women aged 65 years and older. Women were excluded if they were unable to walk without assistance, or if they had undergone a previous bilateral hip replacement. Initially African American women were excluded from the study due to their low incidence of hip fractures, but approximately 10 years after baseline, an additional 662 African American women aged 65 years and older were enrolled in SOF[9] bringing the total enrollment to 10 366 women.

Using methods previously described,[10,11] successful matches to Medicare claims were achieved for 9228 SOF women (92.4% of surviving participants) as of January 01, 1991. Participants at the SOF Portland site were originally recruited into the study through membership in the Kaiser Permanente Northwest (KPNW) health plan, and there was a high rate of Medicare Advantage enrollment (Part C plan) at this site. Thus, SOF Portland participants were also linked to KPNW encounter records as of January 01, 1991. In combining Medicare claims and KPNW encounter records, 9381 SOF participants (93.9% of surviving SOF participants as of January 01, 1991) were linked to claims data.

From January 2002 to April 2004, SOF women were invited back to participate in the Year 16 exam (Visit 8). Of the 10 366 women enrolled in SOF, 3676 attended the Year 16 visit either in the clinic or in their home. Of the 6690 who did not participate in the visit, 1051 completed self-administered questionnaires, 4111 died before Year 16, 872 had already stopped participating in the study, 31 were loss to follow-up, and 625 were only participating in returning post-cards. The present study included 1827 women who participated in a clinic or home visit at the Year 16 exam (n = 3676), had valid actigraphy measures (n = 3052) and who were enrolled in a fee-for-service (FFS) or Kaiser Permanente plan for at least one month (n = 1827). A detailed breakdown of women who were included in the study is provided in Figure 1.

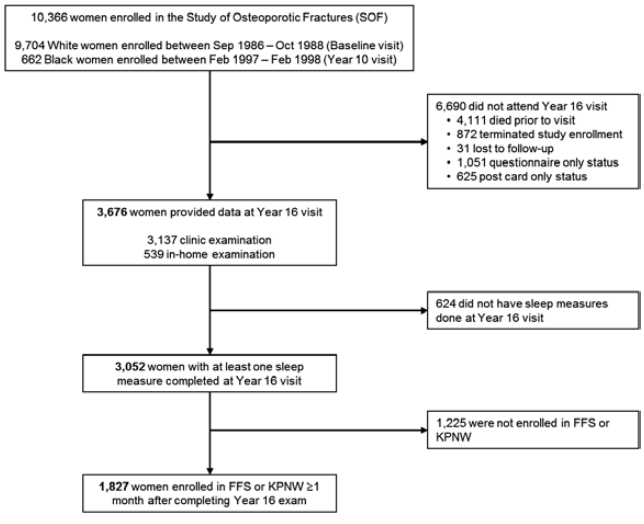

Figure 1—Participant Flow. FFS = Fee-For-Service; KPNW = Kaiser Permanente Northwest.

Wrist Actigraphy

Activity patterns were measured using an octagonal wrist actigraph SleepWatch-O (Ambulatory Monitoring, Inc., Ardsley, NY), which is a small device resembling a wrist watch that is worn on the wrist of the non-dominant hand. Actigraphs contain accelerometers that measure and record movement in 1-minute epochs, and have been shown to provide reliable estimates of sleep–wake activity in comparison to polysomnography.[12] Centralized training and certification were required for clinic staff gathering actigraphy data. Activity data from the actigraph were analyzed using Action W-2 software (Ambulatory Monitoring, Inc.). Participants also completed a sleep diary in which they were asked to record bedtime and wake time, known naps, and intervals during which the actigraph was removed (eg, for bathing). This information was used to aid scoring of the raw data. Actigraphs collected data in three modes, with different methodologies and sensitivities and thresholds to determine movement. The University of California at San Diego sleep scoring algorithm was used for data collected in the digital integration mode (also known as the proportional integration mode), and time-above-threshold, and the Cole–Kripke algorithm was used for data collected in the zero-crossings mode.[13]

Women were asked to wear the actigraph continuously for at least 72 hours, beginning at the time of the Year 16 exam, and to remove it only for bathing or situations in which it might get submerged in water. Time periods in which participants removed the actigraphs were not included in the analyses, and if the actigraph was removed for greater than 10% of the time during the day or for over 2 hours during the night, data from that night were not included in the analyses.

Parameters of sleep/wake patterns that were computed from the actigraphy data included sleep efficiency (SE): the percentage of time (0%–100%) the participant was sleeping from sleep onset (defined as the first 20 continuous minutes of sleep after getting into bed) until the last minute scored as sleep (the following morning); sleep latency (SL): the time from when the participant reported "lights off" until the time scored as sleep onset; time awake after sleep onset (WASO): the number of minutes scored as wake from sleep onset until the end of the last sleep episode while in bed; and TST: the hours per night spent sleeping while in bed after "lights off." All actigraphy measurements were averaged over the total number of nights the actigraph was worn and had valid measures.

Self-Reported Sleep Measures

Women enrolled in SOF also completed the Pittsburgh Sleep Quality Index (PSQI) and the Epworth Sleepiness Scale (ESS) questionnaires at the Year 16 exam. The PSQI is a validated measure of subjective sleep quality and sleep disturbances over a 1-month period. Global PSQI scores range from 0 to 21; higher scores are indicative of worse sleep quality and cutoffs of 5 and 8 have been used to define poor sleep quality.[14–17] The higher cutpoint (>8) was used in this study due to the prevalence of sleep related complaints in this population.

The ESS is a self-administered questionnaire that assesses daytime sleepiness. Participants are asked to rate how likely (from 1 to 3, with 1 being unlikely and 3 being highly likely) they are to doze off in eight typical daily situations. Scores

range from 0 to 24, with a score of 11 or greater indicating excessive daytime sleepiness.[18,19]

Hospitalizations

Data on all-cause hospitalizations and cumulative inpatient days for the 36 month period following the month of the Year 16 examination were obtained from the Medicare Provider Analysis and Review (MedPAR) File for participants enrolled in a FFS plan and from KPNW inpatient encounter files for participants enrolled in a KPNW plan. Follow-up time was censored when participants died, or disenrolled from a Medicare FFS or Kaiser Permanente plan.

Other Measures

Each participant completed a questionnaire and was asked at the year 16 examination about self-reported health status, smoking status, alcohol use, caffeine intake, medical history, whether she lived alone, her living arrangement, medication use, and ability to perform basic activities of daily living. Women were also asked about a physician diagnosis of cardiovascular disease (myocardial infarction, angina, congestive heart failure, and stroke), diabetes, chronic obstructive pulmonary disease, Alzheimer's disease, Parkinson's disease, and cancer (excluding non-melanoma skin cancer). A summary multimorbidity score (range 0–6) was then created and categorized as none, 1, or 2 or more of these selected medical conditions. Depressive symptoms were assessed using the Geriatric Depression Scale (GDS); depression was defined as a GDS score ≥6.[20] Gait speed was measured in m/s by recording the time in seconds to walk 6 meters at usual pace. A modified Mini-Mental State Examination (MMSE)[21] was administered. Probable dementia was defined as a MMSE score lower than 24,[22] self-reported history of dementia or use of medications commonly prescribed for dementia. Body weight was measured using a standard balance beam, or digital scale and height using a wall mounted Harpenden stadiometer. Body mass index was calculated as kg/m^2. Information from the earlier SOF examinations was used to assess self-reported race/ethnicity.

Statistical Analysis

Among the analytical cohort of 1827 women, characteristics of women with and without reduced SE were compared using chi-square tests (categorical variables) and *t* tests (continuous variables). Although multiple sleep/wake parameters were examined, SE was selected for the baseline characteristics table because it had the highest correlation with the other continuous sleep/wake parameters (r^2 = −0.41; −0.94; 0.60 for SL, WASO, and TST, respectively) and was a representative measure of sleep in the cohort.

For the analyses, the sleep parameter predictor variables other than TST were expressed as dichotomous variables based on published cutpoints for sleep disturbances,[23–30] many of which define moderate to severe impairment: SE < 70% (reduced SE) versus ≥ 70%; SL ≥ 1 hour (prolonged SL) versus < 1 hour; WASO ≥ 1.5 hour (greater WASO) versus < 1.5 hour; PSQI > 8 (poorer subjective sleep quality) versus ≤ 8; and ESS > 10 (excessive daytime sleepiness) versus ≤ 10). Based on the possibility that there is a U-shaped association between TST and health-related outcomes, TST was expressed as a three-level predictor: shorter sleep duration (<5 hours/night); normal sleep duration (≥5 and ≤8 hours/night, referent group); and longer sleep duration (>8 hours/night).

For each sleep predictor, we constructed a separate two-part Hurdle Logit-Poisson model[31] to analyze the odds of being hospitalized using a logit function, and then among those hospitalized, we analyzed counts of inpatient days using a log link Poisson regression. The model combines these hospitalization events to estimate the mean annualized number of inpatient days among all participants. From the logit function, we obtained an odds ratio evaluating the odds of being hospitalized (dichotomous) among all women. From the Poisson portion of the model, we obtained the rate ratio (also referred to as an incidence density ratio) among women who were hospitalized. This represents the number of hospitalization days/follow-up time in the group of women with the specific sleep disturbance divided by the number of hospitalization days/follow-up time in the group of women without this disturbance. Due to excess heterogeneity compared to a Poisson model, we used bootstrapping to estimate 95% confidence intervals for all count outcomes.

Analyses were initially performed with a base model adjusted for age and clinic site. Subsequently, multivariable models were adjusted for additional covariates (ie, race, depression, use of antidepressants, cognitive functioning, 6-meter walking speed, self-reported health status, any instrumental activities of daily living (IADL) impairment, number of comorbidities, probable dementia, and living independently) that were associated with hospitalizations or sleep disturbances in univariate models using a threshold of $p < .10$ for inclusion in the multivariate model.

To determine whether the effect of each sleep/wake disturbance predictor was dependent on baseline self-reported health status, we performed analyses including the interaction term between each sleep/wake disturbance and baseline health status for the prediction of risk of hospitalization in multivariable adjusted models. Also, to determine whether there was evidence of a linear association between sleep/wake parameters and risk of hospitalization, we performed sensitivity analyses expressing sleep/wake parameters as continuous variables and estimated the odds ratio of hospitalization per 1 standard deviation worsening in each sleep predictor variable.

All analyses were conducted using SAS version 9.3 (SAS Institute Inc., Cary, NC).

RESULTS

Participant Characteristics

Among the 1827 women, the average age was 83.6 years and 12% were African American. One-fourth of women rated their health status as fair or worse and half reported having one or more impairments in IADL (Table 1). Sleep disruption was common in this cohort. The mean (*SD*) TST measured with actigraphy was 6.7 (1.3) hours. Over a quarter of the women (26.9%) slept and average of less than 5 hours/night and 13.7% slept more than 8 hours/night. One out of every five women (20.4%) took longer than 1 hour to fall asleep, one-third (31.5%) had greater WASO (≥1.5 hours) and 9.5% had reduced SE (<70%). One quarter of the women (25%) self-reported having poorer

Table 1—Baseline Characteristics of 1827 Overall and by Category of Sleep Efficiency.

		Sleep efficiency		
Characteristics	**Analytic cohort (*n* = 1827)**	**≥70% (*n* = 1653)**	**<70% (*n* = 174)**	***p***
Age, years, mean (*SD*)	83.6 (3.9)	83.6 (3.8)	84.1 (4.7)	.18
African American, %	11.6	10.7	20.1	<.001
Fair, poor or very poor health status, %	24.5	23.8	31.0	.034
Current smoker, %	3.3	3.3	3.5	.903
Alcoholic drinks per week in the last 30 days, mean (*SD*)	1.2 (2.9)	1.2 (2.8)	1.2 (3.5)	.995
Daily caffeine intake, mg, mean (*SD*)	147 (150)	147 (150)	153 (157)	.591
One or more IADL impairment, %	51.7	50.0	70.4	<.001
Gait speed, m/s, mean (*SD*)	0.80 (0.27)	0.81 (0.26)	0.66 (0.30)	<.001
Body Mass Index, kg/m^2, mean (*SD*)	26.9 (5.0)	26.8 (4.9)	28.6 (5.6)	<.001
Depression (GDS score ≥6), %	11.7	11.5	13.8	.366
Currently taking antidepressants, %	13.7	12.8	21.8	<.001
Currently taking benzodiazepines, %	6.7	6.7	6.9	.933
MMSE (range 0–30), mean (*SD*)	27.7 (2.0)	27.1 (2.4)	27.8 (2.0)	<.001
Probable dementia, %	11.6	10.7	19.5	<.001
Medical conditions, %				<.001
0	37.5	38.9	24.7	
1	36.1	35.9	37.9	
2 or more	26.4	25.2	37.4	
Stroke, %	13.8	13.6	15.5	.496
Diabetes, %	10.9	10.3	16.1	.020
Chronic obstructive pulmonary disease, %	12.2	11.6	18.4	.009
Cardiovascular disease, %	34.2	32.9	46.6	<.001
Cancer, %	22.5	22.3	23.6	.711
Private home/apartment residence, %	74.8	75.8	65.5	.003

GDS = Geriatric Depression Scale; IADL = instrumental activities of daily living; MMSE = Mini-Mental State Examination.

subjective sleep quality (PSQI > 8) and 11.5% had excessive daytime sleepiness (ESS > 10) (data not shown).

In general, women with reduced SE (<70%) were, on average, slightly older and heavier; more likely to report African American race/ethnicity, disability as manifested by greater IADL impairment, antidepressant use, ≥2 medical conditions (multimorbidity), and poorer health status; more likely have poorer cognitive function and probable dementia; and less likely to live independently (Table 1).

Associations of Sleep Disturbances With Hospitalization

During an average of 2.8 years of follow-up (5041 cumulative person-years of observation), 976 (53%) women were hospitalized at least once. In models adjusted for age and site, the odds of hospitalization was higher among women with reduced SE (odds ration [OR] 2.39, 95% CI 1.69–3.39), those with prolonged SL(OR 1.41, 95% CI 1.11–1.78), those with greater WASO (OR 1.57, 95% CI 1.28–1.93), those with shorter TST (OR 1.98, 95% CI 1.42–2.77) and those with poorer subjective sleep quality (OR 1.33, 95% CI 1.07–1.65) (Table 2). In contrast, longer TST and excessive daytime sleepiness were not related to the odds of hospitalization.

After further adjustment for multiple potential confounders including race, depression, use of antidepressants, cognitive function, gait speed, self-reported health status, IADL impairment, comorbidity score, probable dementia, and living arrangement, most of these associations were substantially attenuated and no longer significant, but associations of reduced SE (OR 1.60 95% CI 1.08–2.38) and shorter TST (OR 1.63, 95% CI 1.12–2.37) with an increased odds of hospitalization remained.

Sensitivity analyses examining the interaction between baseline health status and each sleep/wake disturbance for the prediction of risk of hospitalization did not reach statistical significance (*p*-for-interaction terms = .237 to .868) (data not shown).

Table 2—Association Between Sleep Disturbances and Odds of Hospitalization.

Sleep/Wake disturbance	Age and site adjusted		Multivariable adjusted[a]	
	OR (95% CI)	*p*	OR (95% CI)	*p*
SE <70 vs. ≥70%	2.39 (1.69–3.39)	<.001	1.60 (1.08–2.38)	.02
SL >60 vs. ≤60 min	1.41 (1.11–1.78)	.004	1.08 (0.82–1.41)	.59
WASO ≥90 vs. <90 min	1.57 (1.28–1.93)	<.001	1.13 (0.90–1.43)	.29
TST <5 h vs. 5–8 h	1.98 (1.42–2.77)	.001	1.63 (1.12–2.37)	.02
TST >8 h vs. 5–8 h	1.18 (0.90–1.56)	.26	1.07 (0.79–1.45)	.30
PSQI >8 vs. ≤8	1.33 (1.07–1.65)	.01	1.01 (0.79–1.29)	.94
ESS >10 vs. ≤10	1.14 (0.85–1.53)	.38	0.96 (0.69–1.34)	.82

ESS = Epworth Sleepiness Scale; PSQI = Pittsburgh Sleep Quality Index; SE = sleep efficiency; SL = sleep latency; TST = total sleep time; WASO = Wake after sleep onset.

[a]adjusted for age, clinic site, race, depression, use of antidepressants, cognitive functioning, 6-meter walking speed, self-reported health status, any IADL impairments, medical conditions, probable dementia, and living independently.

In sensitivity analyses examining the associations between sleep/wake parameters expressed as continuous variables and odds of hospitalization, results were in general agreement with those of the primary analyses (see Supplementary Table 1). A 1 *SD* (10.2%) decrease in SE was associated with a 17% increased odds of hospitalization (multivariable odds ratio [MOR] = 1.17, 95% CI 1.04–1.31, p = .009). Although shorter sleep time appeared to be associated with a higher odds of hospitalization, the association did not quite reach the level of significance in the multivariable model (MOR for a 1 *SD* [78.8 minute] decrease in TST 1.09, 95% CI 0.98–1.22, p = .11). Analyses examining WASO expressed as a continuous variable and risk of hospitalization indicated that each 1 *SD* (48 minute) increase in WASO was independently associated with an 18% increased odds of being hospitalized (MOR = 1.18, 95% CI 1.05–1.32, p = .006). Multivariable associations of other sleep parameters expressed as continuous variables and risk of hospitalization were not statistically significant (p > .15).

Associations of Sleep Disturbances With Annualized Rate of Inpatient Days

Among the 976 women who were hospitalized at least once during follow-up, women with greater WASO (rate ratio [RR] 1.20, 95% CI 1.04–1.37) and those with poorer subjective sleep quality (RR 1.18, 95% CI 1.02–1.35) had an approximate 1.2-fold increase in the rate ratio of inpatient days/year in models adjusted for age and site (Table 3). However, these associations were attenuated and no longer significant in multivariable models adjusted for multiple potential confounders. Among women hospitalized, there was no evidence of associations of reduced SE, prolonged SL, shorter TST, longer TST or excessive daytime sleepiness with the rate ratio of inpatient days/year in models adjusted for age and site or multivariable-adjusted models.

Among all women, mean inpatient days/year adjusted for age and site were greater among women with reduced SE, those with prolonged SL, those with greater WASO, those with shorter TST and those with poor subjective sleep quality compared with their respective referent groups (Table 3). For example, women with reduced SE had an average of 2.90 (95% CI 2.37–3.51) inpatient days/year compared with 2.00 inpatient days/year (95% CI 1.84–2.17) among women without reduced SE. After further adjustment for potential confounders, these differences between women with and those without each of these specific sleep disturbances were attenuated and no longer statistically significant. Mean inpatient days/year among all women were not significantly different among women with longer TST or those with excessive daytime sleepiness compared with their respective referent groups in either models adjusted for age and site or multivariable-adjusted models.

DISCUSSION

We found that objectively measured sleep disturbances among older women including reduced SE, prolonged SL, greater WASO, and shorter TST were each associated with an increased risk of hospitalization and a greater average number of inpatient days/year. In addition, subjectively assessed poorer sleep quality, but not excessive daytime sleepiness, was associated with a higher risk of hospitalization and greater number of inpatient days/year. These associations were explained in part by a greater burden of comorbidities, worse mobility, and poorer health status among women with sleep disruption, but reduced SE and shorter TST were independent predictors of hospitalization risk despite accounting for these, and other prognostic indicators. Our findings highlight the complex and overlapping relationships between sleep and health.

Our results are in general agreement with those of prior studies conducted in younger populations that have suggested an association of poorer self-reported sleep with greater healthcare utilization.[5–7,32–36] A short-term study[7] of 373 young and middle-aged adults enrolled in a Health Maintenance Organization reported that individuals with insomnia complaints had greater disability; functional impairment; self-reported days in bed; and higher total health care costs. In an analysis of data collected in the Health and Retirement Study (HRS)[5] of 14 355 adults aged 55–64 years, participants who reported two or more insomnia symptoms had a 1.7-fold higher odds of self-reported

Table 3—Rate Ratio of Hospitalization Days by Category of Sleep Disturbance Among Women With Atleast One Hospitalization and Mean Inpatient Hospital Days by Category of Sleep Disturbance among All Women.

	Rate ratio (95% CI)[a] of hospitalization days among women with at least one hospitalization		Mean (95% CI) rate of inpatient days per year among all women	
Sleep/Wake disturbance	**Age and site adjusted**	**Multivariable adjusted[b]**	**Age and site adjusted**	**Multivariable adjusted[b]**
SE				
<70%	1.05 (0.86–1.26)	0.96 (0.76–1.19)	2.90 (2.37–3.51)	2.21 (1.65–2.83)
≥70%	1.00 (referent)	1.00 (referent)	2.00 (1.84–2.17)	1.88 (1.72–2.05)
SL				
>60 min	1.15 (0.98–1.33)	1.10 (0.93–1.29)	2.60 (2.17–3.05)	2.11 (1.74–2.53)
≤60 min	1.00 (referent)	1.00 (referent)	1.96 (1.79–2.13)	1.87 (1.69–2.05)
WASO				
≥90 min	1.20 (1.04–1.37)**	1.03 (0.90–1.18)	2.69 (2.34–3.03)	2.03 (1.74–2.33)
<90 min	1.00 (referent)	1.00 (referent)	1.83 (1.66–2.01)	1.86 (1.68–2.06)
TST				
≤5.0 h	1.09 (0.90–1.30)	1.11 (0.89–1.38)	2.76 (2.25–3.33)	2.46 (1.92–3.06)
5–8 h	1.00 (referent)	1.00 (referent)	1.93 (1.76–2.10)	1.80 (1.64–1.97)
>8 h	1.19 (0.99–1.41)	1.18 (0.96–1.44)	2.48 (2.03–2.98)	2.19 (1.69–2.80)
PSQI				
>8	1.18 (1.02–1.35)**	1.12 (0.95–1.29)	2.57 (2.20–2.97)	2.06 (1.69–2.42)
≤8	1.00 (referent)	1.00 (referent)	1.92 (1.76–2.10)	1.86 (1.68–2.03)
ESS				
>10	1.20 (0.96–1.46)	1.10 (0.87–1.32)	2.56 (2.00–3.15)	2.02 (1.56–2.50)
≤10	1.00 (referent)	1.00 (referent)	2.02 (1.86–2.19)	1.90 (1.73–2.07)

ESS = Epworth Sleepiness Scale; PSQI = Pittsburgh Sleep Quality Index; SE = sleep efficiency; SL = sleep latency; TST = total sleep time; WASO = Wake after sleep onset.

[a]Bootstrapping with 1000 samples used to estimate 95% confidence intervals and *p*-values.

[b]Adjusted for age, clinic site, race, depression, use of antidepressants, cognitive functioning, 6 meter walking speed, self-reported health status, any impairments in instrumental activities of daily living, number of comorbidities, probable dementia, and living independently.

**$p < .05$

hospitalization compared to those without symptoms after accounting for demographic characteristics and medical conditions. Our study expands upon these previously published investigations with its inclusion of both subjective and objective measurements of sleep disturbance, linkage with claims and encounter data to confirm hospitalization and inpatient days, and comprehensive consideration of multiple potential confounders.

Our findings suggest that the higher risk of hospitalization among older women with sleep disturbances including greater sleep fragmentation and shorter sleep duration is in large part explained by health related and demographic factors among women with sleep disruption. While it is possible that sleep disturbances are simply a marker of worse underlying health, we did not find evidence that the association between sleep disturbances and hospitalization depended on category of health status at baseline. It is also plausible that disrupted sleep exacerbates co-existing medical conditions, aggravating their severity and increasing the risk of hospitalization. Previous randomized trials[37–39] evaluating behavioral and pharmacologic approaches for the management of insomnia in older adults (mean age 60–65 years) have demonstrated the efficacy of treatment in improving insomnia symptoms and quality of life. However, future trials are warranted to evaluate whether incorporation of sleep interventions (such as cognitive behavior therapy for insomnia) into chronic disease case management programs reduces subsequent health care utilization and costs among adults later in life. Incorporation of a sleep treatment component into disease management and care for complex/high risk older adults would be an innovative and holistic patient-centered approach.

Our study has several strengths including the large, well characterized cohort representative of community-dwelling women later in life, objective and subjective measures of sleep disturbances with wrist actigraphy and validated questionnaires, linkage to inpatient claims data and consideration of

major confounding and mediating factors. However, this study has a number of limitations. Results may not be generalizable to other populations including men, older adults residing in institutions, and non-white populations. Polysomnography was only performed in a small subset of participants and power was insufficient to examine the association between sleep disordered breathing and inpatient health care utilization. Analyses of weekday versus weekend effects were not feasible due to an insufficient number of weekend nights. Future studies are warranted to evaluate additional outcomes including outpatient health care utilization, long-term nursing home placement, and total health care costs. Additionally, our study has an observational design. Thus, residual confounding remains a potential explanation for our findings and we are unable to establish the causality of the relationship between poor sleep and hospitalization. Data on hospitalizations were derived from administrative claims data and thus may have inaccuracies unique to the use of administrative data that were not designed for research purposes. Finally, comprehensive information on socioeconomic status was not available in claims or cohort data.

In conclusion, our findings suggest that subjectively assessed poorer sleep quality and objectively measured reduced SE, prolonged SL, greater WASO, and shorter TST were each associated with higher risk of hospitalization in this cohort of women late in life. These associations were explained in part, by poorer health status and greater mobility limitation and comorbidity burden among those women with sleep disturbances. These results underscore the complex and overlapping relationships between sleep and health in the aged population.

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SUPPLEMENTARY MATERIAL

Supplementary data are available at *SLEEP* online.

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