ORIGINAL ARTICLE

Associations of insomnia symptoms with subsequent health services use among community-dwelling U.S. older adults

Marian Tzuang[1],[*],[ ], Jocelynn T. Owusu[1],[ ], Jin Huang[2], Orla C. Sheehan[2],[3], George W. Rebok[1],[2],[4], Misti L. Paudel[5], Emerson M. Wickwire[6],[7], Judith D. Kasper[8] and Adam P. Spira[1],[2],[4]

[1]Department of Mental Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD [2]Center on Aging and Health, Johns Hopkins School of Medicine, Baltimore, MD [3]Division of Geriatric Medicine and Gerontology, Johns Hopkins School of Medicine, Baltimore, MD [4]Department of Psychiatry & Behavioral Sciences, Johns Hopkins School of Medicine, Baltimore, MD [5]Optum, Health Economics and Outcomes Research, Eden Prairie, MN [6]Department of Psychiatry, University of Maryland School of Medicine, Baltimore, MD [7]Sleep Disorders Center, Division of Pulmonary and Critical Care Medicine, Department of Medicine, University of Maryland School of Medicine, Baltimore, MD [8]Department of Health Policy and Management, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD

*Corresponding author. Marian Tzuang, 624 North Broadway, Room 802, Baltimore, MD 21205. Email: yuan.tzuang@ucsf.edu.

Abstract

Study Objectives: Determine the association of insomnia symptoms with subsequent health services use, in a representative sample of U.S. older adults.

Methods: Participants were 4,289 community-dwelling Medicare beneficiaries who had continuous fee-for-service Medicare coverage 30 days before, and 1 year after the National Health and Aging Trends Study (NHATS) Round 1 interview. Participants reported past-month insomnia symptoms (i.e. sleep onset latency >30 min, difficulty returning to sleep) which we categorized as 0, 1, or 2 symptoms. Outcomes were health services use within 1 year of interviews from linked Medicare claims: emergency department (ED) visits, hospitalizations, 30-day readmissions, home health care (all measured as yes/no), and number of hospitalizations and ED visits.

Results: Overall, 18.5% of participants were hospitalized, 28.7% visited the ED, 2.5% had a 30-day readmission, and 11.3% used home health care. After adjustment for demographics, depressive and anxiety symptoms, medical comorbidities, and BMI, compared to participants with no insomnia symptoms, those with two insomnia symptoms had a higher odds of ED visits (odds ratio [OR] = 1.60, 95% confidence interval [CI] = 1.24–2.07, $p < 0.001$), hospitalizations (OR = 1.29, 95% CI = 1.01–1.65, $p < 0.05$), and 30-day readmissions (OR = 1.88, 95% CI = 1.88–3.29, $p < 0.05$). Reporting 2 insomnia symptoms, versus no insomnia symptoms, was associated with a greater number of ED visits and hospitalizations (incidence rate ratio (IRR) = 1.52, 95% CI = 1.23–1.87, $p < 0.001$; IRR = 1.21, 95% CI = 1.02–1.44, $p < 0.05$, respectively) after adjusting for demographic and health characteristics.

Conclusions: Among older adults, insomnia symptoms are associated with greater health services use, including emergency department use, hospitalization, and 30-day readmission. Targeting insomnia may lower health services use.

Statement of Significance

Although insomnia has been linked to a range of adverse health outcomes in older adults, research on the burden of insomnia on health services use is limited. Studies that have investigated the association of insomnia and health services use prospectively with claims-based data are particularly scarce. Using a nationally representative survey with linked Medicare claims data, this study found that individuals who reported a greater number of insomnia symptoms (i.e. difficulty initiating and/or maintaining sleep), compared to those without insomnia symptoms, were more likely to visit the emergency department, be hospitalized, and be readmitted within 30-day postdischarge. Future studies are needed to evaluate whether treating or preventing insomnia in older adults may reduce health services utilization.

Key words: insomnia; sleep; health services use; Medicare; older adults

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Introduction

Clinically, insomnia is characterized by complaints of difficulty falling asleep, difficulty staying asleep, and complaints of poor sleep quality along with daytime functional consequences [1, 2]. These symptoms are common among community-dwelling older adults, with prevalence estimates ranging upwards of 50% [3].

With increasing age, adults are more likely to live with multiple chronic conditions and functional limitations, which could increase health services use. According to a study that analyzed data from a 5% sample of Medicare claims from 2000–2011, per capita Medicare fee-for-service (FFS) spending increased with age, with beneficiaries age 80 or above accounting for a disproportionate share of total spending [4]. This study also found that while hospitalizations accounted for the largest proportion of per capita FFS spending, per capita spending increased for skilled nursing facilities, home health care, and hospice among beneficiaries well into their 90s [4].

There is a small but growing body of evidence linking insomnia to greater health care costs and utilization in older adults. Relative to direct medical costs among matched non-insomnia controls, 6-month direct medical expenditures were $1,143 (2007 USD) higher for a large sample of older individuals with untreated insomnia enrolled in three self-insured, employer-sponsored health plans [5]. This finding was replicated recently in a large study of Medicare beneficiaries in which, compared to controls, beneficiaries with untreated insomnia demonstrated significantly greater all-cause healthcare expenditures as well as increased costs across multiple points of service [6]. In addition to the associations of insomnia with health care expenditures, insomnia has been linked with several healthcare and long-term care services among older adults. Older individuals with insomnia symptoms were more likely to have had physician office visits [7], emergency department visits [8], hospitalizations [6, 8, 9], home health care [8], nursing home use [8], and subsequent nursing home placements [10]. In the only such study that obtained an objective measure of sleep with wrist actigraphy, greater wake after sleep onset (a reflection of wakefulness) and lower sleep efficiency (i.e. percentage of total time in bed actually spent in sleep), were each associated with a greater odds of subsequent nursing home placement or residence in a personal care home in older women [11].

Despite aforementioned results suggesting that insomnia is associated with greater use of health services, gaps remain in the literature that warrant further research. For example, several prior studies were restricted to either older men or older women, or used data from specific private health plans, thus limiting the generalizability of the findings to the general population of community-dwelling older adults. Further, few studies have assessed prospective associations of insomnia with health services use, precluding an evaluation of a potential causal association. To minimize potential recall bias, studies are needed that use objective measures of health services use from the payer perspective, such as claims-based data, rather than patient-reported health services. Finally, more studies are needed to determine the impact of insomnia across a wider range of health services. To address these gaps in the literature, the present study was designed to assess the prospective association of insomnia symptoms with the use of common and costly health services including emergency department visits, hospitalizations and readmissions, and home health care in a nationally representative sample of U.S. older adults.

Methods

Study population and data source

Participants were enrolled in the National Health and Aging Trends Study (NHATS), an ongoing nationally representative cohort study of adults aged 65 and older in the U.S. led by the Johns Hopkins Bloomberg School of Public Health and funded by the National Institute on Aging. The sampling frame for selecting the NHATS sample is the Medicare enrollment file. Approximately 96% of the U.S. population ages 65 and older is enrolled in Medicare, making the enrollment file a good approximation of the target population. The NHATS investigators reported comparable distribution of demographic characteristics comparing data from NHATS, Medicare, and the census [12]. The NHATS interview includes data on residence, health conditions such as insomnia symptoms, housing/household, functional status, insurance, and labor force participation. The annual interviews are conducted by lay interviewers in home environments. Linkage to Medicare beneficiary files is available for every NHATS participant [12]. Of the 8,245 Round 1 participants enrolled in 2011, 4,470 community-dwelling participants were continuously enrolled in Medicare Fee-For-Service plans (FFS; Medicare Parts A, B) from 30 days before the Round 1 interview date, until death or 365 days of follow-up, whichever came first. In NHATS, linkage is available to Medicare claims (e.g. hospital and outpatient visits, home health care, hospice files) among participants concurrently enrolled in FFS plans. Part C (Medicare Advantage) claims data were unavailable for NHATS participants at the time of analyses. We excluded 181 participants missing one or more of baseline insomnia data for a final analytic sample of 4,289 participants. NHATS protocols were reviewed and approved by the Johns Hopkins Bloomberg School of Public Health Institutional Review Board.

Insomnia symptoms

Two items measured insomnia symptoms in the month prior to the NHATS Round 1 in-person interviews. The first asked how frequently participants took more than 30 min to fall asleep; the second asked how frequently the participants had difficulty returning to sleep when waking up before wanting to get up. Responses were recorded on a 5-point Likert scale (1 = every night, 2 = most nights, 3 = some nights, 4 = rarely, 5 = never). Responses of "every" or "most" were recategorized to indicate as having the insomnia symptom; and responses of "some nights," "rarely," or "never" as not having the insomnia symptom. The sum of these two items indicates the number of insomnia symptoms (range: 0–2). A sensitivity analysis was carried out where responses of "some nights" were categorized as indicating the presence of the insomnia symptom as done in an earlier study in NHATS [13].

Health services utilization

Data on health services use were obtained from linked-NHATS Medicare FFS claims data in the 365 days following the Round 1

interview date. Each participant was linked to multiple Medicare claims files by a unique, deidentified beneficiary identification number. Follow-up time was censored when participants disenrolled from Medicare FFS or died.

Emergency department visits.
Emergency department (ED) visit records are collected from the revenue center codes in both the inpatient and outpatient claims data files (0450, 0451, 0452, 0456, 0459, 0981) [14]. The total number of ED visits was summed during the follow-up period.

Hospitalizations.
All-cause hospitalizations are identified through the Medicare Part A inpatient base claim file that contains information on admission and discharge dates, diagnosis, procedure performed, FFS reimbursement amount, and the hospital provider number. We collapsed claims in the inpatient base claim file into one record if they were either from the same hospital stay or reflected transfers from one facility to another during the same hospital stay. The number of hospitalizations during the follow-up period was calculated by counting the number of records per beneficiary identification number from the inpatient base claim files within a specified time period. Furthermore, using data from the same file, we defined readmission as unplanned hospital readmissions that occurred within 30 days of discharge from the initial discharge [14, 15].

Home health services.
Data on home health services claims were extracted from the Home Health Agency (HHA) revenue file, which contains FFS claims submitted by Medicare home health agency providers for reimbursement of home health services, using revenue center codes 042X–044X, 055X–058X, 0590, 0599.

Demographics and health characteristics

Demographic characteristics, including participants' age (in categories: 65–69 years; 70–74; 75–79; 80–84; 85–89; and 90+ years), sex (male, female), race/ethnicity (white, non-Hispanic; black, non-Hispanic; Hispanic; or other non-Hispanic race [American Indian, Alaska Native, Asian, Native Hawaiian, Pacific Islander, or other]), and the highest level of education (less than high school, high school degree and/or some college/trade school, Associate's degree or greater) were collected at Round 1. Body mass index (BMI; in kg/m^2) was calculated using self-reported height and weight data and participants were classified as: underweight (BMI < 18.5 kg/m^2), normal (healthy) weight (BMI between 18.5–24.9 kg/m^2), overweight (BMI between 25 and 29.9 kg/m^2), or obese (BMI ≥ 30 kg/m^2) [16]. Depressive and anxiety symptoms were measured by the Patient Health Questionnaire-2 [17] and Generalized Anxiety Disorder-2 [18] scales, respectively. The two items in each scale were summed to yield a score for each measure (range: 0–6), with higher scores indicating greater severity of depressive or anxiety symptoms. At Round 1, participants were also asked whether a healthcare provider had told them that they have or have had a heart attack, heart disease, hypertension, arthritis, osteoporosis, diabetes, stroke, or cancer. We categorized participants as having 0 or 1, 2, 3, or 4 medical conditions. Additionally, participants were

asked to report past-month use of sleep medication. Responses were recorded on a 5-point Likert scale (1 = every night, 2 = most nights, 3 = some nights, 4 = rarely, 5 = never). Responses of "every" and "most nights" were recategorized to indicate sleep medication use; and responses of "some nights," "rarely," or "never" to indicate no sleep medication use. Participants were also asked about past-month pain (yes/no). All demographic and health characteristics were ascertained in 2011 as part of the Round 1 interview.

Statistical analysis

We compared participant characteristics by the number of insomnia symptoms at baseline (Round 1) using χ^2 tests for categorical variables and simple linear regression for continuous variables. Known potential confounders (i.e. age, education, race/ethnicity) and those that were associated with both insomnia (the predictor of interest) and one or more of health services use outcomes (at the $p < 0.05$ level) in our data were included as covariates in the models. To quantify the association of insomnia symptoms with health services use, we fit a series of regression models with a number of insomnia symptoms (0 [ref], 1, 2) as the primary predictor. Our first outcomes were binary measures reflecting any claims-based ED visits, all-cause hospitalizations, all-cause 30-day readmissions, and home health service, analyzed using logistic regression. The outcomes of the number of ED visits and the number of hospitalizations were analyzed as count variables using negative binomial regression models due to overdispersion of the count data relative to the Poisson distribution ((α's < 0.001) [19]. To examine the extent to which demographic characteristics alone, or in combination with depressive and anxiety symptomatology and medical comorbidities, explained observed associations, we fit a series of multivariable-adjusted models. The base model (Model I) included demographics (i.e. age, sex, race/ethnicity, educational attainment). Model II adjusted for Model I variables as well as depressive and anxiety symptoms. Model III adjusted for Model I variables and both BMI and number of medical conditions. Model IV adjusted for all covariates in the previous models. We also performed a sensitivity analysis in which we lowered the threshold for our definition of "insomnia symptoms," by including responses of "some nights" (vs. prior criteria of "every" or "most" nights) as indicating the presence of an insomnia symptom. We then repeated analyses.

To account for the differential probabilities of selection and nonresponse bias, we applied survey weights constructed by NHATS. All statistical analyses were performed in Stata 14.0 (StataCorp, College Station, TX).

Results

Participant characteristics

Of the 4,289 sample participants, 47.3% were 75 years of age or over, 55.7% were women, 84.7% were non-Hispanic white, and 79.3% had completed a high school education (Table 1). Almost 72% of participants had two or more medical conditions, and 27.6% were obese (BMI ≥ 30 kg/m^2). The average PHQ-2 and GAD-2 scores were 0.96 and 0.93, respectively. A total of 205 participants (4.6%) died within 365 days of the Round 1 interview date.

Table 1. Participant characteristics in the National Health and Aging Trends Study in 2011 by number of insomnia symptoms*

Unweighted N	Total sample (column %) N = 4,289	0 Insomnia symptoms n = 3,043	1 Insomnia symptom n = 763	2 Insomnia symptoms n = 483	p-value
Age, %					0.326
65–69	27.5	71.3	17.1	11.6	
70–74	25.2	73.5	17.5	9.0	
75–79	19.7	71.7	18.4	9.9	
80–84	15.4	71.8	16.3	11.9	
85–89	8.6	67.0	20.5	12.5	
90+	3.6	70.8	19.5	33 (9.7)	
Sex, %					<0.0001
Male	44.3	75.5	15.8	8.7	
Female	55.7	68.6	19.2	12.2	
Race/ethnicity, %					<0.01
White, non-Hispanic	84.7	72.3	17.8	9.9	
Black, non-Hispanic	7.3	70.0	17.1	12.9	
Hispanic	3.1	70.5	16.7	12.8	
Other†	4.9	61.7	19.1	19.2	
Education, %					<0.0001
<High School	20.7	63.2	20.1	16.7	
High School Graduate	27.0	68.7	20.7	10.6	
>High School	52.3	76.5	15.3	8.2	
BMI (kg/m²)‡, %					0.121
<18.5	2.3	67.9	16.3	15.8	
18.5–24.9	32.3	72.4	16.7	10.9	
25–29.9	37.8	73.5	16.5	10.0	
≥30.0	27.6	743 (68.7)	20.4	10.9	
PHQ-2§, mean ± SD	0.96 ± 0.03	0.74 ± 0.03	1.30 ± 0.06	1.92 ± 0.09	<0.0001
GAD-2‖, mean ± SD	0.93 ± 0.03	0.69 ± 0.02	1.35 ± 0.08	1.89 ± 0.08	<0.0001
No. of medical conditions, %					<0.0001
0 or 1	28.1	78.7	14.5	6.8	
2	25.1	75.9	16.3	7.8	
3	21.2	70.7	20.0	9.3	
4+	25.6	61.6	20.2	18.2	

*NHATS 2011; N = 4,289; community-dwelling older adults continuously enrolled in Medicare FFS for 365 days or who died within 365 days from the interview date. Responses of "every night" or "most nights" were categorized to indicate the presence of insomnia symptoms.
†Other race/ethnicity includes American Indian, Alaska Native, Asian, Native Hawaiian, Pacific Islander, or other.
‡BMI = body mass index.
§PHQ-2 = 2-item Patient Health Questionnaire (depressive symptoms).
‖GAD-2 = 2-item Generalized Anxiety Disorder Questionnaire (anxiety symptoms).

With respect to insomnia symptoms, 3,043 (71.7%) participants reported zero symptoms, 763 (17.7%) participants reported 1 insomnia symptom, and 483 (10.7%) participants reported two insomnia symptoms. Overall, 22.3% (*n* = 984) of participants had responses consistent with our criteria for having the insomnia symptom of taking more than 30 min to fall asleep, and 16.7% (*n* = 745) of participants met our criteria for the symptom of difficulty returning to sleep after waking earlier than desired. The presence of insomnia symptoms was associated with female sex, non-White race/ethnicity, lower education level, greater depressive symptoms (PHQ-2), greater anxiety symptoms (GAD-2), and higher number of medical conditions (all *p* < 0.0001, except race/ethnicity, *p* < 0.01; Table 1).

Associations of insomnia with health services use

During follow-up, 28.7% of participants had at least one ED visit, 18.5% had been hospitalized at least once, 2.5% had at least one readmission within 30 days of a prior hospitalization, and 11.3% had used home health care services. On average, participants visited the ED 0.53 (standard error [SE] = 0.02) times and were hospitalized for 0.29 (SE = 0.01) times within 365 days of the Round 1 interview.

In models adjusted for demographic characteristics (Model I), endorsement of both insomnia symptoms was associated with each type of subsequent health services use (Table 2). Relative to individuals with no insomnia symptoms, those reporting two insomnia symptoms had a greater odds of ED use (odds ratio [OR] = 2.12, 95% CI = 1.69–2.66, *p* < 0.001), all-cause hospitalization (OR = 1.84, 95% CI = 1.48–2.28, *p* < 0.01), all-cause 30-day readmission (OR = 2.89, 95% CI = 1.71–4.87, *p* < 0.001), and use of home health care (OR = 1.98, 95% CI = 1.42–2.75, *p* < 0.001). The associations between insomnia symptoms and each category of health services use (with the exception of home health care use) were attenuated but remained statistically significant after additional adjustment for depressive and anxiety symptoms and health characteristics (Model IV). The association between reporting both insomnia symptoms and home health care use remained significant (OR = 1.58, 95% CI = 1.11–2.25, *p* < 0.05) after adjustment for BMI and medical conditions (Model III), but the

associations were no longer significant in models adjusting for demographics and depressive and anxiety symptoms (Model II) or in the fully adjusted model (Model IV). Overall, there appears to be a dose–response relationship where the strengths of the associations for those having both insomnia symptoms are stronger than having just one insomnia symptom across various types of health services.

Associations of insomnia with rates of ED visits and hospitalizations

The associations of insomnia symptoms with rates of ED visits and hospitalizations are shown in Table 3. Relative to individuals with no insomnia symptoms, those with two insomnia symptoms had a 1.5-fold increase in the incidence rate of ED visits (IRR = 1.52, 95% CI = 1.23–1.87, $p < 0.001$) and a 21% increase in

Table 2. Associations between number of insomnia symptoms and odds of subsequent health services use: results from multivariable logistic regression analyses*

	Health services use unweighted n (%)	Model I[†] OR[¶] (95% CI[#]) $n = 4,239$	Model II[‡] OR (95% CI) $n = 4,191$	Model III[§] OR (95% CI) $n = 4,095$	Model IV[‖] OR (95% CI) $n = 4,048$
Emergency department visit					
0 Insomnia symptoms	915 (25.4)	Reference	Reference	Reference	Reference
1 insomnia symptom	280 (33.7)	1.47 (1.18, 1.82)**	1.29 (1.03, 1.63)*	1.35 (1.07, 1.70)*	1.23 (0.97, 1.57)
2 insomnia symptoms	220 (42.1)	2.12 (1.69, 2.66)***	1.76 (1.39, 2.22)***	1.77 (1.37, 2.28)***	1.60 (1.24, 2.07)***
All-cause hospitalization					
0 Insomnia symptoms	578 (16.4)	Reference	Reference	Reference	Reference
1 insomnia symptom	181 (21.7)	1.39 (1.11, 1.73)**	1.23 (0.97, 1.57)	1.26 (1.01, 1.57)*	1.19 (0.94, 1.50)
2 insomnia symptoms	142 (27.0)	1.84 (1.48, 2.28)***	1.47 (1.16, 1.85)**	1.45 (1.14, 1.83)**	1.29 (1.01, 1.65)*
All-cause 30-day readmission					
0 Insomnia symptoms	82 (1.9)	Reference	Reference	Reference	Reference
1 insomnia symptom	28 (3.0)	1.58 (0.97, 2.56)	1.31 (0.80, 2.16)	1.44 (0.85, 2.43)	1.30 (0.77, 2.21)
2 insomnia symptoms	27 (5.7)	2.89 (1.71, 4.87)***	2.03 (1.14, 3.64)*	2.25 (1.34, 3.79)**	1.88 (1.08, 3.29)*
Home health care					
0 Insomnia symptoms	407 (9.8)	Reference	Reference	Reference	Reference
1 insomnia symptom	125 (12.9)	1.27 (0.96, 1.70)	1.05 (0.78, 1.42)	1.09 (0.81, 1.48)	0.96 (0.71, 1.30)
2 insomnia symptoms	107 (18.9)	1.98 (1.42, 2.75)***	1.40 (0.99, 1.97)	1.58 (1.11, 2.25)*	1.26 (0.88, 1.80)

*NHATS 2011; $N = 4,289$; community-dwelling older adults continuously enrolled in Medicare FFS for 365 days or who died within 365 days from the interview date. Responses of "every night" or "most nights" were categorized to indicate the presence of insomnia symptoms.
†Model I adjusted for demographic characteristics (age, sex, race/ethnicity, education).
‡Model II adjusted for Model I covariates + mental health characteristics (depressive and anxiety symptoms).
§Model III adjusted for Model I covariates + physical health characteristics (BMI, number of medical conditions).
‖Model IV fully adjusted for demographic, mental health, and physical health characteristics.
¶OR = odds ratio.
#CI = confidence interval.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 3. Number of insomnia symptoms and incidence rate ratio of ED visits and hospitalizations: results from multivariable negative binomial regression models*

	Health services use unweighted mean ± SE	Model I[†] IRR[¶] (95% CI[#]) $n = 4,239$	Model II[‡] IRR (95% CI) $n = 4,191$	Model III[§] IRR (95% CI) $n = 4,095$	Model IV[‖] IRR (95% CI) $n = 4,048$
Emergency department visit					
0 Insomnia symptoms	0.46 ± 0.02	Reference	Reference	Reference	Reference
1 insomnia symptom	0.61 ± 0.04	1.35 (1.13, 1.60)**	1.17 (0.98, 1.40)	1.28 (1.07, 1.53)**	1.16 (0.96, 1.40)
2 insomnia symptoms	0.95 ± 0.07	2.15 (1.79, 2.58)***	1.72 (1.41, 2.09)***	1.70 (1.40, 2.07)***	1.52 (1.23, 1.87)***
All-cause hospitalizations					
0 Insomnia symptoms	0.25 ± 0.01	Reference	Reference	Reference	Reference
1 insomnia symptom	0.31 ± 0.02	1.25 (1.01, 1.53)*	1.09 (0.88, 1.35)	1.16 (0.95, 1.41)	1.15 (0.97, 1.36)
2 insomnia symptoms	0.55 ± 0.06	2.27 (1.73, 2.97)***	1.69 (1.29, 2.22)***	1.65 (1.28, 2.13)***	1.21 (1.02, 1.44)*

* NHATS 2011; $N = 4,289$; community-dwelling older adults continuously enrolled in Medicare FFS for 365 days or who died within 365 days from the interview date. Responses of "every night" or "most nights" were categorized to indicate the presence of insomnia symptoms.
†Model I adjusted for demographic characteristics (age, sex, race/ethnicity, education).
‡Model II adjusted for Model I covariates + mental health characteristics (depressive and anxiety symptoms).
§Model III adjusted for Model I covariates + physical health characteristics (BMI, number of medical conditions).
‖Model IV fully adjusted for demographic, mental health, and physical health characteristics.
¶IRR = incident rate ratio.
#CI = confidence interval.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

the incidence rate of all-cause hospitalizations (IRR = 1.21, 95% CI = 1.02–1.44, *p* < 0.05) in the fully adjusted model (Model IV).

Sensitivity analysis

In a sensitivity analysis, we redefined insomnia as requiring an insomnia symptom occurring at least "some nights," as opposed to at least "most nights." Under this definition, 42.4% of participants had zero symptoms, 27.0% had one insomnia symptom, and 30.6% had two insomnia symptoms. In models adjusted for demographic characteristics (Model I), endorsement of both insomnia symptoms was associated with each type of subsequent health services use. However, none of the associations between insomnia symptoms and each category of subsequent health services use was significant after adjustment for all of the potential confounders (Model IV) (Supplemental Table 1). There was an almost 1.3 times greater incidence rate of ED visits among individuals who reported having two insomnia symptoms compared to those without insomnia symptoms after adjustments for demographics, BMI, and number of medical conditions (Model III: IRR = 1.27, 95% CI = 1.11–1.45, *p* < 0.01), but the association was attenuated and became non-significant in the fully adjusted model (Model IV: IRR = 1.13, 95% CI = 0.97–1.32, *p* = 0.067) (Supplemental Table 2).

We performed two additional sets of analyses to evaluate how pain and sleep medication use might have impacted the observed associations of insomnia symptoms with health services use. For the first set of analyses, we added past-month pain to the Model III covariates (i.e. demographics, BMI, number of medical conditions) to create Model IV. The new Model V is the fully adjusted model, adjusted for demographics, mental health, physical health characteristics, and pain. Endorsement of two insomnia symptoms, compared to no insomnia symptoms, was associated with all types of health services use in models adjusting for demographics, BMI, number of medical conditions, and pain (Model IV). However, in the fully adjusted model, only reports of two insomnia symptoms remained statistically significantly associated with any ED visits (Model V: OR = 1.58, 95% CI = 1.22–2.04, *p* ≤ 0.01) and any all-cause 30-day readmission (Model V: OR = 1.85, 95% CI = 1.06–3.24, *p* ≤ 0.05) (Supplemental Table 3). Compared to those reporting no insomnia symptoms, participants who reported two insomnia symptoms had a 1.5 times greater incidence rate of ED visits (Model V: IRR = 1.49, 95% CI = 1.21–1.82, *p* < 0.001) and 1.4 times greater incidence rate of all-cause hospitalization (Model V: IRR = 1.38, 95% CI = 1.06–1.81, *p* < 0.05) in the fully adjusted model (Supplemental Table 4).

In the second set of analyses, we added sleep medication use to the Model III covariates, creating Model IV, and we also fit Model V—the fully adjusted model with all covariates (i.e. demographics, mental health, physical health characteristics, and sleep medication use). Relative to reports of no insomnia symptoms, reporting two insomnia symptoms was associated with greater use of all types of health services in models adjusting for demographics, BMI, number of medical conditions, and sleep medication use (Model IV). In the fully adjusted model (Model V), compared to those reporting no insomnia symptoms, individuals reporting two insomnia symptoms had a greater odds of ED use (OR = 1.57, 95% CI = 1.21–2.03, *p* < 0.001) and a greater odds of all-cause 30-day readmissions (OR = 1.82, 95% CI = 1.04–3.19, *p* < 0.05) (Supplemental Table 5). In the fully adjusted model

(Model V), relative to individuals with no insomnia symptoms reported, those endorsing two insomnia symptoms had a 51% greater incidence rate of ED visits (IRR = 1.51, 95% CI = 1.22–1.87, *p* < 0.001) and a 38% greater incidence rate of all-cause hospitalizations (IRR = 1.38, 95% CI = 1.05–1.79, *p* < 0.05) in the fully adjusted model (Supplemental Table 6).

Individuals close to death tend to receive greater health care that may result in biased estimates. Thus, we also ran sensitivity analyses excluding participants who died during follow-up. Relative to reporting no insomnia symptoms, having two insomnia symptoms was associated with a 50% greater odds of ED visits [OR = 1.50, 95% CI = 1.14–1.96, *p* < 0.01 (Supplemental Table 7)] and a 1.5-fold increase in the incidence rate ED visits [IRR = 1.52, 95% CI = 1.19–1.93, *p* < 0.01] in the fully adjusted model (Model IV).

Discussion

Using a large, representative sample of U.S. adults aged 65 and older, we found that reporting frequent difficulties initiating sleep and returning to sleep was associated with greater odds of any ED visits, all-cause hospitalizations, or all-cause 30-day readmissions after adjusting for potential confounders including demographics, anxiety and depressive symptoms, BMI, and medical conditions. We also found positive associations of insomnia symptoms with the number of ED visits and the number of all-cause hospitalizations, even after accounting for medical and mental health characteristics. The estimated associations attenuated (though remained significant) with additional adjustments for medical and mental health comorbidities. These findings not only underscore the complex relationships among physical and mental health and sleep but also highlight the salience of disturbed sleep as a modifiable risk factor impacting population-level health and economic outcomes from the payer perspective.

In the present study, slightly over 28% of participants reported at least one insomnia symptom, which is lower than estimates reported in prior studies of community-dwelling older adults [3, 20]. We defined the presence of insomnia symptoms as those occurring at least "most nights" of the week, a closer reflection of the criteria for insomnia disorder in the Diagnostic and Statistical Manual of Mental Disorders, 5th Edition (DSM-5) which require the symptoms to have occurred ≥3 times per week. Therefore, the definition of insomnia symptoms in our primary analysis is more stringent and likely contributed to the lower prevalence observed. As expected, results from the sensitivity analysis showed that the prevalence of insomnia increased (to 57.6%) and the magnitude of the associations with each category of health services use decreased when we lowered the threshold for insomnia symptoms to include responses of "some nights" as indicating the presence of an insomnia symptom.

Our findings extend the results of prior studies linking poorer self-reported sleep with subsequent health services use among older adults. With regards to hospitalizations, a large study (*N* = 14,355) of adults aged 55 and older using data from the Health and Retirement Study found that a greater number of insomnia symptoms was associated with a greater odds of self-reported hospitalization after controlling for demographic characteristics, medical conditions, and depressive symptoms [8]. In a complementary study of the relationships between

actigraphic sleep and hospitalization, lower sleep efficiency and shorter total sleep time each were associated with greater odds of hospitalization among older women based on linked claims data [9]. To our knowledge, our study is the first to link greater insomnia symptoms with all-cause 30-day readmissions (i.e. unplanned readmissions within 30 days postdischarge) after controlling for potential confounders. The 30-day all-cause readmission rate is a key measure for the quality of patient care in the United States and was consistently found to be the highest among Medicare patients [21]. More research is needed to discern the mechanisms through which insomnia might increase readmissions.

In addition to hospitalizations, we were also able to assess the impact of insomnia on other costly health services that have been under-investigated in the existing literature. Although there is some evidence that individuals with insomnia are more likely to have had emergency department visits, most of these studies were conducted in younger adults or in clinical populations [5, 22–24], limiting the generalizability of findings to community-dwelling older adults. Our study is among the first to show that insomnia is associated with increased visits to the emergency department among older adults living in the community, supporting the results of a recent study linking untreated insomnia (defined by ICD-9 codes and Medicare medication claims) to increased ED use and elevated ED costs in a random sample of Medicare beneficiaries [6].

To our knowledge, our study is only the second study that has examined home health care use, and consistent with the first study, we too found that insomnia increases the risk for the subsequent use of home health care services [8]. Demand for home health care is expected to grow as people are living longer [25], again highlighting the need for additional research to replicate this finding and more importantly, investigations into whether treating insomnia would reduce the utilization of this costly service.

Our findings suggest that insomnia may be an important marker of and perhaps a contributor to a range of health problems. In community-dwelling older adults, considerable evidence links insomnia and use of pharmacological sleep aids to falls [26–29]. Falls, in turn, cause the majority of hip fractures in older adults that result in functional impairments and injuries that are strong predictors for hospital admissions and premature nursing home placement [30, 31]. This is one example of how sleep problems, if unaddressed, may lead to increased burden on the health care system. Alternatively, psychopathology may explain some of the association between insomnia and health services use. We found that, after further adjustment for anxiety and depressive symptoms, the magnitude of the associations of insomnia symptoms with each type of health services use decreased. The close links between sleep and psychopathology are well-established. For example, there is a bidirectional and highly comorbid relationship between sleep disturbances (including insomnia symptoms) and depression [32]. Although outside the scope of this study, more research is needed to examine whether concurrent treatment of insomnia and depressive symptoms could lead to better management of this comorbidity, and subsequently lower health services utilization. Poor sleep has also been shown to influence inflammatory response activation, which has been implicated as a contributor to a range of negative health outcomes including cardiovascular disease [33] and cancers [34], which may lead to

a greater likelihood of hospitalizations. Research investigating links between insomnia symptoms and cause-specific hospitalization and ED visits would shed light on the potentially mediating mechanisms or disorders that could also be targeted to prevent health services use.

This study has several strengths, including a prospective design and use of a large, well-characterized sample of community-dwelling older adults. This is also only one of few studies in this population that has used claims-based data, as opposed to participant report, to ascertain health services use. Older adults may be systematically more or less likely to report health services use based on certain characteristics (e.g. cognitive impairment), so the use of objective claims-based data removes the threat of recall bias. Additionally, we were able to capture a wider range of health services that are commonly used and that impose a high financial burden, including ED visits, readmissions, and home health care services.

Our study also had several limitations. Our sample consisted only of NHATS participants who were enrolled in the Medicare fee-for-service plan, so our findings may not generalize to those enrolled in Medicare Advantage (Part C) plans. Older adults who enrolled in Medicare Advantage represented roughly 33% of the Medicare population in 2017 [35], and enrollment is growing every year. As a group, they have been found to be younger, wealthier, healthier (e.g. less medically complex), and more racially/ethnically diverse when compared to those enrolled in Medicare FFS, although recent trends indicate that these demographic and clinical characteristic differences are diminishing [36]. In addition, the measurement of insomnia symptoms in this study was limited to only two symptoms, and there were no data available on daytime consequences. A broader, validated insomnia measure or use of sleep diaries, and a measure of daytime consequences would have enhanced the study. Further, in future research, more detailed insomnia measures that capture frequency, chronicity, and severity of symptoms would help clarify which of these aspects of insomnia are most predictive of health services use. Moreover, although insomnia is conventionally diagnosed based on patient report, we recognize that self-reported sleep commonly disagrees with objectively measured sleep in older adults [37, 38], and it is, therefore, unclear whether results would differ if data from objective sleep measures such as wrist actigraphy or polysomnography were collected. Future studies using both objective sleep measures and claims-based health services data could provide important information beyond that captured by self-report. Lastly, it is possible that unmeasured confounding exists and affects our estimates of the relationship between insomnia symptoms and health care utilization. Although we adjusted for multiple potential confounders such as sleep medication use, pain, and medical comorbidities, we were unable to account for medications that affect sleep (e.g. sedating antidepressants) that were taken to treat conditions other than sleep, or for sleep disorders (e.g. sleep-disordered breathing, restless legs syndrome) that are linked to both insomnia symptoms and health services use. Although we adjusted for some risk factors for sleep-disordered breathing (e.g. male sex, BMI), we were not able to directly account for its role in the associations under study.

Despite the high prevalence of insomnia among older adults and the well-documented associations with a range of adverse health outcomes (including increased healthcare utilization and costs as ours and previous studies have

suggested), insomnia remains under-detected and under-diagnosed, especially among older adults [39, 40]. More physician education about insomnia and how it manifests in older adults, and the incorporation of discussions about sleep problems during patient care might help remove some of the barriers to recognition, diagnosis, and treatment of insomnia in this population. It is also important to increase public awareness of insomnia, so that individuals suffering from it can consult with their healthcare provider earlier on. Furthermore, it is well-known that a hospital is not a sleep-friendly environment due to noise and light levels and patients being awakened to take vitals or other procedures, and those who have preexisting insomnia symptoms are particularly susceptible to sleep and circadian rhythm disturbances while hospitalized [41]. Incorporating best practices that support sleep and strengthen circadian rhythms in hospitalized patients may ultimately help reduce future health services use, but further research is needed in this area. As identified earlier, sedative-hypnotic medication has been linked to falls and fractures in older adults. Therefore, treating insomnia with the evidence-based, non-pharmacological Cognitive Behavioral Therapy for Insomnia (CBT-I) could reduce falls, and while there may be an increase in health services use for this purpose, it could ultimately decrease the use of more costly healthcare such as ED visit and hospitalizations. To further support the case for early treatment of insomnia, a recent review demonstrated the cost-effectiveness of insomnia treatments and in particular, showed a good "return on investment" for treating insomnia in the long run by lowering indirect costs such as poorer workplace performance, health services use, and risk of accidents [40].

In conclusion, findings from the present study suggest that, among U.S. older adults, insomnia symptoms are associated with greater subsequent use of health services including all-cause hospitalizations and 30-day readmissions, ED visits, and home health care. High health care use and associated expenditures can have far-reaching consequences for older adults, contributing to depletion of personal financial security, and imposing a greater burden on the health care system. The convergence of rapid population aging and rising U.S. health care costs underscores the importance of identifying factors, such as insomnia, that if treated, may lower health services use. Studies such as the present one highlight the importance of poor sleep health, which with appropriate and timely treatment, could optimize health more broadly and alleviate healthcare burden.

Supplementary material

Supplementary material is available at *SLEEP* online.

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