Longitudinal associations between time-varying insomnia symptoms and all-cause healthcare services utilization among middle-aged and older adults in the US

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Abstract

This study examines longitudinal associations between time-varying insomnia symptoms (including difficulty initiating sleep, difficulty maintaining sleep, early-morning awakenings, and nonrestorative sleep) and all-cause healthcare services utilization (HSU; overnight hospital stays, nursing home stays, and home healthcare services) among middle-aged and older adults. Data were obtained from 2002 through 2018 waves of the Health and Retirement Study in the US for a population-representative sample of 13,168 adults (aged ≥50 years; mean [SD] age= 66.8±9.4; females= 57.7%; ≥2 comorbid medical conditions= 52.5%). A marginal structural modeling approach and generalized estimating equations were implemented to capture time-varying biological, psycho-cognitive, lifestyle, or behavioral health factors and to adjust for selection bias due to differential loss to follow-up. At baseline, 38.9% of respondents reported experiencing at least one insomnia symptom. During the 16-year follow-up, 72.9%, 17.9%, and 35.1% reported overnight hospital stays, nursing home stays, and home healthcare services utilization, respectively. Higher numbers of insomnia symptoms on a cumulative scale were associated with more overnight hospital stays, nursing home stays, and home healthcare services utilization. Further, experiencing each of difficulty initiating and maintaining sleep, and nonrestorative sleep, as standalone symptoms, was associated with a higher likelihood of HSU compared to those not experiencing any of these symptoms. Independent associations of early-morning awakening with nursing home stays and home healthcare utilization were not significant. The results emphasize the roles of screening and addressing symptoms of insomnia among middle-aged and older adults or those prone to sleep disorders to reduce avoidable HSU. Future investigations should focus on the underlying causes and health systems pathways linking insomnia symptoms to HSU.

Introduction

Insomnia is the most prevalent sleep disorder.[1–3] More than 50% of middle-aged, and up to 75% of older adults experience at least one insomnia symptom on a regular basis in the United States (US).[4–6] Insomnia symptoms such as difficulty initiating and maintaining sleep, early-morning awakenings, nonrestorative sleep, and their many daytime consequences are more common among middle-aged and older adults compared to younger aged groups.[5,7,8] Insomnia imposes substantial burdens on individuals, society, and the healthcare system due to its quality of life and other cascading health effects.[9] People experiencing insomnia symptoms often report both dissatisfaction with sleep and diminished daytime functioning which impact their social, emotional, occupational, and physical well-being.[9,10] The total direct and indirect costs attributed to insomnia in the US are estimated to range between 92.5 to 107.5 billion dollars annually.[7,11]

Insomnia symptoms are associated with the onset of a range of chronic health conditions including cardiometabolic risk factors such as diabetes and hypertension, and increased risks of cardiovascular diseases, cerebrovascular diseases, and cardiovascular-related or all-cause mortality.[1,12–17] In addition, they are considered significant risk factors for mental health problems such as depression, anxiety, and

other psychiatric disorders, as well as cognitive decline and dementia.[1,5,18–22] Furthermore, insomnia symptoms are potential risk factors for other health conditions such as weakened immune system and substance abuse disorders involving alcohol, nicotine, opiates, cannabis, or other substances.[23,24] In terms of the underlying causes, a complex, bidirectional association between insomnia symptoms and health morbidities and behaviors has been observed.[5] For example, experiencing insomnia symptoms and other sleep disturbances could increase the risk of chronic health conditions such as obesity, depression, or lead to substance abuse disorders and result in maladaptive health behaviors. These conditions, in turn, might contribute to insomnia symptoms, resulting in a vicious cyclical effect.[5]

Existing literature suggests associations between insomnia symptoms and higher healthcare services utilization (HSU). However, these findings are primarily based on observational studies using cross-sectional data.[25–31] Studies focusing on longitudinal associations between insomnia symptoms and HSU are scarce. Furthermore, to our knowledge, the limited number of prospective studies available to-date [32–37] employed only static measures of insomnia symptoms, usually at baseline, and followed individuals for HSU without considering the dynamic, complex, and bidirectional nature of these evolving associations in the life-course of individuals. In examining associations between insomnia symptoms and adverse health outcomes or HSU, it is important to take a life-course approach because sleep reflects dynamic neurobehavioral processes that change with age and interacts bidirectionally with cognitive, physical, and behavioral health factors that often evolve over time.[38] Moreover, the course of insomnia symptoms is often characterized by a waxing-and-waning pattern;[1] and insomnia as a clinical disorder can be a situational, recurrent, or persistent health problem.[9] Therefore, it is critical to account for the time-dependent nature of the symptoms when assessing their immediate as well as downstream impacts on HSU.

The current study builds on the limitations of prior literature and fills a gap in the research on insomnia symptoms and their potential link to subsequent HSU. We hypothesized that (1) among middle-aged and older adults, experiencing higher numbers of insomnia symptoms are prospectively associated with a likelihood of increased overnight hospital stays, nursing home stays, and higher home healthcare services utilization; and (2) that experiencing each insomnia symptom, individually, is associated with a higher likelihood of utilizing each of the healthcare services compared to those not experiencing the symptom.

Methods

Data Source, Study design, and the Sample

Data were drawn from 2002 through 2018 waves of the Health and Retirement Study (HRS), an ongoing biennial, longitudinal and population-representative national survey of adults 50 years and older and their spouses (regardless of age) in the US. Initiated in 1992, HRS collects information on individuals' demographics, health, cognition, employment, income, assets, healthcare utilization and costs, health

insurance, and family structure in the US. Details of the survey design and methodology can be accessed online at Documentation | Health and Retirement Study (umich.edu) and have been discussed elsewhere.[39–41]

This study used the 2002 survey wave as the baseline because it was the wave when questions on insomnia symptoms were first introduced to the core HRS questionnaire. Proxy respondents (usually a family member or next-of-kin) were excluded from baseline and all follow-up survey waves because they did not answer the cognition and depression assessment questions on behalf of the participants. The final analytical sample was limited to 13,168 self-respondents who were ≥ 50 years old in 2002. These respondents were followed for 16 years, through the end of the 2018 survey wave. We censored the respondents at the wave they died, dropped out, lost to follow-up, or by the end of the 2018 survey wave, whichever came first. The HRS protocol was approved by the Institutional Review Board at the University of Michigan and verbal consent is obtained from respondents prior to each new interview or re-interviews.[42] The current study's inclusion and exclusion criteria are presented in the supplement as Fig. 1. We followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines in the current study.

Measurements of Healthcare services Utilization

The HRS collects information on HSU at each wave through respondents' self-report of healthcare services utilization since their previous interviews or during the past two years. Information on three measures of HSU was extracted from the dataset and each was treated as a repeated binary outcome (yes vs. no) in our analyses. We analyzed overnight hospitalization, the first key dependent variable, through the survey question, "*In the last two years\Since previous wave interview have you been a patient in a hospital overnight?"* Nursing home stay was then assessed based on the survey question, "*In the last two years\Since previous interview, have you been a patient overnight in a nursing home, convalescent home, or other long-term health care facility?"* Lastly, home healthcare utilization was determined based on whether, in the last two years or since the previous wave interview, the respondent received any care provided at home by medically trained persons (e.g., professional nurses, visiting nurse's aides, physical or occupational therapists, chemotherapists, and respiratory oxygen therapists). The measurements of HSU in the HRS are reported to have strong construct validity.[43]

Measurements of Insomnia Symptoms

Questions evaluating insomnia symptoms in the HRS were adopted from a modified version of the Jenkins Sleep Scale.[44] The respondents were asked how often they have difficulties in "*falling asleep* (initiating sleep)," "*waking up during the night* (maintaining sleep)," "*waking up too early and not being able to fall asleep again* (early-morning awakening)," and how often they feel "*really rested* (nonrestorative sleep)" when they wake up in the morning. The response options for each question include "*most of the time*," "*sometimes*," and "*rarely or never*." Following other sleep studies,[15,45–48] the respondents were ascertained to have experienced the insomnia symptom when they answered "most of the time" in the first three questions and when they answered "rarely or never" in the last question. Thus,

each insomnia symptom was operationalized through a binary variable, “yes vs. no,” in the analyses. Then, at each follow-up, we summed across the four symptoms and categorized the respondents into those who experienced no symptoms, one, two, three, or all four symptoms. This measure represents the number of experienced insomnia symptoms by respondents on a cumulative scale. Since the HRS did not evaluate respondents for three of the independent insomnia symptoms in 2008 and 2012, respondents’ last observation was carried forward for those symptoms and waves. The temporal sequence of events was preserved in the current study by operationalizing insomnia symptoms and covariate measures at waves 2002 through 2016, and subsequent evaluations for HSU at waves 2004 through 2018 (see Fig. 2, the supplement).

Measurements of Time-Invariant and Time-Varying Covariates

Choice of the study covariates was based on their associations with HSUs (the key dependent variables) and insomnia symptoms (our key independent variables), as documented in the extant scientific literature. Time-invariant “baseline-only” sociodemographic covariates in the current study included: respondents’ self-reported sex (male vs. female); race and ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, and non-Hispanic others); educational attainment (less than high school or general educational development [GED], high-school graduate, some college, and college and above); marital status (married or living as married vs. other [separated, divorced, widowed, and never married]); poverty level, determined through the poverty threshold levels form the US census bureau and respondents’ family composition[39,49] (dichotomized as household income above the poverty threshold vs. household income below the poverty threshold); and respondents’ census region (Northeast, Midwest, South, and West).

The potential time-varying covariates included a set of socioeconomic, biological, functional, psycho-cognitive, psychophysiological, health insurance coverage, and health behavior characteristics. The socioeconomic covariates included whether the respondent was working for pay (yes vs. no). Biological covariates were respondents’ age in years, body mass index (BMI), calculated as weight in kilograms divided by the square of height in meters (kg/m^2) and categorized as (normal or underweight (< 25 kg/m^2), overweight (25-29.9 kg/m^2), and obese (≥ 30 kg/m^2). The “underweight” BMI category, at each wave, was collapsed with the “normal” category because of having small numbers of observations. Comorbid medical conditions, derived from eight self-reported doctor’s diagnosis of medical conditions (hypertension, diabetes, cancer [excluding skin cancer], chronic lung disease, heart conditions, stroke or transient ischemic attack, emotional, nervous, or psychiatric problems, and arthritis or rheumatism), all summed and categorized as having (none, one, or two and more) comorbid conditions.

Time-varying functional capabilities were evaluated as limitations in any of the five activities of daily living (ADL) (i.e., walking across a room, dressing, bathing, eating, and getting in and out of bed), and any of the five instrumental activities of daily living (IADL) (i.e., taking medications, preparing meals, managing money, using phone, and shopping for groceries), each dichotomized into (yes vs. no). The cognitive and psychological measures were the cognitive functioning score and the modified 8-item

Center for Epidemiologic Studies Depression (CES-D) scale score, both were measured on a continuous scale, and are considered valid and reliable assessments of cognition and depression.[50–54] For this study, one item which evaluates "*restless sleep*" was removed from the CES-D scale score to minimize operational confounding of the scale with the outcomes.[55,56] Moreover, one psychophysiological measure was incorporated; whether the respondent is often troubled with pain (yes vs. no). Health insurance coverages were ascertained through self-report of possessions of government-sponsored health insurance plans (yes vs. no), and at least one private health insurance plan (yes vs. no). Lastly, time-varying health behavior covariates included respondents' smoking status (current, former, and never), alcohol consumption (yes vs. no), and engagements in vigorous physical activity (yes vs. no).

Analytic Approach

The respondents' descriptive characteristics at baseline were first calculated, followed by an analysis of the baseline characteristics of study participants who reported any use of healthcare services (i.e., overnight hospital stays, nursing home stays, and home healthcare services) at least once during the 16 years of follow-up. A marginal structural model (MSM) analysis[57–59] was employed to evaluate the longitudinal associations between time-varying insomnia symptoms and HSUs. MSMs are a class of causal models used for causal inferencing in epidemiology and developed by Robins et al.[57–60] In longitudinal observational studies that analyze repeated measures of exposures, researchers often encounter such challenges as confounding factors, colliders, mediators, and other complex and dynamic relationships that exist among the variables. In the present study, time-varying insomnia symptoms can be influenced by their preceding values and confounders, and they could, in turn, influence their subsequent values and those of the confounders. Further, in these circumstances, there is possibility of potential bidirectional associations between insomnia symptoms and HSUs. Thus, using standard, traditional methods of longitudinal data analysis would not allow for accurate and unbiased estimates of the investigated associations because they cannot account for the dynamic nature of the explanatory variables nor selection bias. Therefore, MSMs can ideally be used for estimating the average causal effect of time-varying variables such as insomnia symptoms on respondents' HSUs.[59–61] A distinct advantage of the MSM approach is that the generated results approximate those obtained from randomized controlled trials in a practical way.[57,59]

Implementing an MSM analysis required calculating two inverse probability weights, namely, the inverse probability of treatment weight (IPTW) to account for time-varying confounders and, the inverse probability of censoring weight (IPCW) to account for differential loss to follow-up due to study withdrawal, loss to follow-up, or death of study participants. Final total MSM weights, with all confounding and selection bias removed, were derived from multiplying IPTWs by IPCWs. For MSM notation and weight estimation, see Methods 1 of the Supplement.

The calculated final MSM weights were then applied to the pooled data (81,627 person-waves) to fit repeated measures models using generalized estimating equations (GEE) for each HSU as an outcome with robust variance estimators and an independent working correlation matrix that generated causal

odds ratios (OR) and 95% robust confidence intervals (CI).[59,62] These models were the final step in analyzing the associations between insomnia symptoms and HSUs. Since each respondent could have repeated HSUs during follow-up, robust variance estimates of standard errors were sought to account for the clustering of observations within respondents over time.[63] In the GEE models, only baseline, time-invariant variables were adjusted for, because the effects of these variables, unlike the time-varying confounders, were not actively incorporated into the estimation of the MSM weights.[62] Interaction terms between the primary exposure (i.e., insomnia symptoms) and the time-invariant variables were assessed. Several sensitivity analyses were performed to test the robustness of the MSM weights and the validity of the final model results (see Methods 2, the supplement). Traditional models of analysis were used to calculate the ORs for comparison purposes (see Results 4, the supplement). All analyses were conducted using SAS 9.4 statistical software (SAS Institute Inc., Cary, NC, USA). The statistical significance threshold was set at P-value ≤ 0.05.

Results

Respondents' general characteristics at baseline and follow-up

Table 1 shows the descriptive characteristics of the respondents at baseline. The respondents were primarily females (57.7%), non-Hispanic whites (83.8%), had some college or more education (44.0%), were married (63.3%), had an annual household income above the poverty threshold (92.5%), and were residing in the Southern parts of the US (36.4%). At baseline, about 38.9% were experiencing at least one insomnia symptom. The proportions of those experiencing difficulty initiating sleep, difficulty maintaining sleep, early-morning awakenings, and nonrestorative sleep were 11.9%, 25.5%, 11.9%, and 13.5%, respectively. The respondents were working for pay (39.4%), had a mean age (±SD) of 66.8 (±9.4) years, were overweight or obese (65.4%), had two or more comorbid medical conditions (52.5%), reported at least one ADL limitation (13.7%), and at least one IADL limitation (10.8%). Their baseline mean (±SD) cognitive functioning score and CES-D scale score were 16.0 (± 4.4) and 1.20 (± 0.03), respectively. About 29.4% reported often being troubled with pain. About 58.4% indicated being covered by government health insurance plans, and 73.9% reported having at least one private health insurance plan. Respondents at baseline were current or former smokers (59.8%), were consuming alcohol (50.4%), and reported never being engaged in vigorous physical activity (56.6%).

[TABLE 1 GOES ABOUT HERE]

Tables 2 provides the baseline characteristics of the respondents who utilized each of the three healthcare services at least once during the 16-year follow-up. During follow-up, 8,838 (72.9%), 2,173 (17.9%), and 4,251 (35.1%) respondents reported overnight hospital stays, nursing home stays, and home health care services utilization, respectively.

[TABLES 2 GOES ABOUT HERE]

Longitudinal associations between time-varying insomnia symptoms and all-cause HSUs

Table 3 presents a summary of the key results of the marginal structural GEEs. In brief, respondents experiencing one (OR=1.25; 95% CI: 1.19–1.31, *P*<.001), two (OR=1.40; 95% CI: 1.31–1.50, *P*<.001), three (OR=1.64; 95% CI: 1.50–1.78, *P*<.001), or four (OR=1.84; 95% CI: 1.58–2.14, *P*<.001) insomnia symptoms had higher odds of overnight hospital stays compared to asymptomatic respondents. Respondents having trouble initiating sleep (OR=1.24; 95% CI: 1.16–1.32, *P*<.001), maintaining sleep (OR=1.18; 95% CI: 1.12–1.23, *P*<.001), early-morning awakenings (OR=1.07; 95% CI: 1.01–1.14, *P*=.03), and nonrestorative sleep (OR=1.26; 95% CI: 1.19–1.34, *P*<.001) had higher odds of overnight hospital stays compared to those not experiencing the symptoms.

In terms of nursing home stays, respondents experiencing one (OR=1.21; 95% CI: 1.09–1.33, *P*<.001), two (OR=1.29; 95% CI: 1.13–1.49, *P*<.001), three (OR=1.39; 95% CI: 1.17–1.67, *P*<.001), or four (OR=1.54; 95% CI: 1.17–2.04, *P*<.001) insomnia symptoms had higher odds of nursing home stays compared to those experiencing no insomnia symptoms. For each insomnia symptom as a standalone symptom; those reported difficulty initiating sleep (OR=1.22; 95% CI: 1.07–1.39, *P*=.004), difficulty maintaining sleep (OR=1.14; 95% CI: 1.03–1.26, *P*=.009), and nonrestorative sleep (OR=1.32; 95% CI: 1.17–1.48, *P*<.001) had higher odds of nursing home stays compared to those without the symptoms.

Finally, in terms of home healthcare services, respondents experiencing one (OR=1.31; 95% CI: 1.22–1.40, *P*<.001), two (OR=1.52; 95% CI: 1.39–1.67, *P*<.001), three (OR=1.72; 95% CI: 1.52–1.95, *P*<.001), or four (OR=1.72; 95% CI: 1.40–2.09, *P*<.001) insomnia symptoms had higher odds of utilizing home healthcare services compared to those who were asymptomatic. Similarly, respondents having difficulty initiating sleep (OR=1.24; 95% CI: 1.13–1.36, *P*<.001), maintaining sleep (OR=1.18; 95% CI: 1.10–1.27, *P*<.001), and nonrestorative sleep (OR=1.34, 95% CI: 1.23–1.46, *P*<.001) had higher odds of home healthcare services utilization compared to their counterparts without the symptoms.

[TABLE 3 GOES ABOUT HERE]

Sensitivity Analyses

The estimated odds ratios obtained through the sensitivity analyses did not produce qualitatively different estimates in the final analyses compared to those obtained from our originally selected MSM weights (see Results 1, 2, & 3, the Supplement). Further, the statistical conclusions or direction of associations between the number and type of insomnia symptoms and HSU did not significantly differ. Thus, the results of our sensitivity analyses support our MSM models' validity and reliability in investigating the study objectives and confirm the robustness of the empirical outcomes.

Discussion

Using a population-representative sample of 13,168 middle-aged and older adults (aged ≥ 50 years) in the US, we investigated longitudinally hypothesized associations between specific time-varying insomnia symptoms and three categories of HSUs including overnight hospital stays, nursing home stays, and home healthcare services utilization. Our findings indicate that experiencing higher numbers of insomnia symptoms including difficulty initiating sleep, difficulty maintaining sleep, early morning awakenings, and nonrestorative sleep was associated, on a cumulative scale, with higher odds of all three types of examined HSUs. Further, experiencing difficulty initiating and maintaining sleep and nonrestorative sleep were independently associated with higher utilization of the healthcare services compared to those not reporting the symptom. Respondents reporting early-morning awakenings had higher odds of overnight hospital stays compared to their counterparts without the symptom. However, early-morning awakening was not independently associated with nursing home stays and home healthcare services utilization.

Despite the differences in methodology, study design, length of follow-up, and sample size, some of our findings are similar to a few prior prospective studies. Among a sample of 14,355 adults aged 55 years and older, for example, Kaufmann et al.[34] found that respondents who reported one or two and more symptoms of difficulty initiating and maintaining sleep, early-morning awakenings, and nonrestorative sleep at baseline had a higher likelihood of hospitalization. However, these authors found no associations with nursing home placement or home healthcare services utilization after two years of follow-up. Similarly, in a sample of community-dwelling older adults aged 65–98 years, Pollak et al.[35] found that experiencing difficulty initiating sleep, difficulty maintaining sleep, and early morning awakening at baseline were associated with nursing home placement in men, but not in women, during the subsequent three and half years follow-up.[35] More recently, Tzuang et al.[36] investigated the associations between experiencing the two insomnia symptoms of difficulties initiating sleep and returning to sleep and several HSUs at one year of follow-up among 4,289 community-dwelling older Medicare beneficiaries participating in the National Health and Aging Trends Study (NHATS) in the US. Compared to those with none of the symptoms, older adults who reported both symptoms at baseline had a higher likelihood of emergency department (ED) visits, all-cause hospitalizations, and all-cause 30-day hospital readmission at one year of follow-up, but no associations were found with home healthcare services utilization. Further, those who experienced both symptoms had higher frequencies of ED visits and hospitalizations, compared to those with none of the symptoms.[36]

In contrast to our findings, two prospective studies[33,37] utilizing data from the Study of Osteoporotic Fractures (SOF) for community-dwelling older women linked to Medicare claims data in the US reported that experiencing sleep disturbances, poor quality sleep, and insomnia symptoms among women at baseline were not associated with the risk or length of hospitalization,[33,37] or risk of skilled nursing facility stay[33] within three years of follow-up. Those reported associations were mainly attenuated and deemed nonsignificant after adjustments for their baseline confounding factors such as comorbid medical conditions, functional limitations, depression, and cognitive functioning status of the

respondents. Evidence from other cross-sectional studies of general adult populations indicate the presence of associations between independent, or combinations of, insomnia symptoms, including difficulty initiating and maintaining sleep, early-morning awakening, nonrestorative sleep, and daytime sleepiness, and a wide range of healthcare and long-term healthcare services. Those scholarly works indicated that experiencing insomnia symptoms were associated with higher hospitalizations,[16,29,31] ED visits,[27,29] physician visits,[16, 25–28,31] home healthcare utilization,[29] prescription refill and overuse of medications such sleep, pain, and antidepressant drugs,[16,26,27] and over-the-counter medications use.[27]

Our results have significant implications on national healthcare costs. In 2019 in the US, the total healthcare expenditures reached $3.8 trillion and the out-of-pocket expenditures averaged at $1,240 per capita. [64,65] Total costs accrued due to hospital care, nursing home, and home healthcare services accounted for almost 40%.[66] If current trajectories continue, the total healthcare spending is projected to reach $6.2 trillion, or 20% of the Gross Domestic Product, by the year 2028. [67] The healthcare costs in the US are mainly driven by higher utilization rates and higher prices, [68] and the true attributing factors to higher healthcare utilization and expenditures are an aging population and higher prevalence of chronic conditions. [69] It is projected that the number of adults age 65 years and older will more than double from 46 million to 98 million between 2014 and 2060. [70]

The aging population is indeed a major challenge for not only individual healthcare providers but also policymakers at the healthcare system level.[69] In this regard, primary and secondary preventive measures and management of disease symptoms have been proposed as successful strategies to curb or reduce utilization and health expenditures.[71] Since the incidence of insomnia increases continuously with age,[5] and because insomnia symptoms are major contributors to adverse health outcomes and chronic diseases, identifying and targeting these symptoms, as potentially modifiable risk factors, could deem successful strategies. Most of the increase in utilization and growth in healthcare expenditures over the last few decades in the US has been linked to the modifiable risk factors of major chronic conditions such as cardiovascular diseases, cancer, and dementia.[72] Indeed, up to 50% of cancer cases,[73] and over 70% of all cardiovascular morbidities and mortalities are attributed to modifiable risk factors.[74] Therefore, healthy lifestyle choices such as maintaining good quality sleep, physical activity, maintaining a healthy weight, quitting or not smoking, and following a healthy diet regimen could improve the quality of life, and ultimately reduce healthcare services utilization and healthcare expenditures.[72,73,75–77]

To our knowledge, this is the first study to extensively evaluate the effects of several time-varying insomnia symptoms on all-cause HSUs over a long follow-up period while accounting for time-dependent and evolving confounding factors and selection bias. The results are generalizable to the middle-aged and older adult populations (aged ≥ 50 years) in the US. However, despite the strengths of the study, there are several limitations to note when interpreting our results. Measures of insomnia symptoms and HSUs were subjective, and data were self-reports by the respondents. A detailed evaluation of sleep may require using more accurate diagnostic tools like actigraphy and polysomnography. However, insomnia symptoms are in the subjective domain, and clinical diagnosis of insomnia disorder and its primary

symptoms are exclusively dependent on self-report. Objective sleep measures derived from devices such as polysomnography or actigraphy are less sensitive or specific than self-reports in identifying insomnia symptoms or clinical insomnia disorder, and often not feasible in wide-scale prospective studies.[78] Further, although found to have strong construct validity,[43] self-reports of HSU measures are still liable to inaccuracy due to bias including recall bias or social desirability bias. In addition, some limitations of the HRS dataset include the absence of variables related to obstructive sleep apnea (OSA), excessive daytime sleepiness, duration of insomnia symptoms, daily total sleep duration, and inconsistent information on the use of sleep medication. Considering these unmeasured potential confounders could have strengthened our analyses. Therefore, the results are interpreted assuming no unmeasured confounding. We tried to compensate for some of these factors using different approaches. For example, although we could not directly account for OSA, other respondent characteristics such as age and BMI were used as its proxies. Previous research indicates a positive correlation between increasing age, BMI, and the probability of having OSA.[3] Indeed, the incidence of OSA increases twofold with every 10-year increase in age, and 80% of those aged 71 and older have OSA.[5]

Conclusion And Health Policy Implications

In a population-representative cohort of middle-aged and older adults with a 16-year follow-up, we found supporting evidence that several insomnia symptoms were associated, both cumulatively and independently, with a higher likelihood of overnight hospital stays, nursing home stays, and higher home healthcare services utilization. Therefore, early detection and management of insomnia symptoms, especially among the age groups studied here, are crucial to individual health and could also prevent downstream adverse health outcomes and HSUs. Assessments of sleep quality among middle-aged and older adults can start with a general evaluation of sleep satisfaction followed by a thorough screening for insomnia symptoms. Preventive interventions and screening should be sought in both clinical and non-clinical community-level settings and among people more at risk of adverse health outcomes. Screening for insomnia symptoms can be performed using the existing brief, reliable, valid, and easy-to-use insomnia symptoms questionnaires. Once assessed and diagnosed, it is essential to properly manage the symptoms. There are several pharmacological and nonpharmacological behavioral treatments for insomnia symptoms.[5] The existing pharmacological medications (e.g., benzodiazepines, nonbenzodiazepine hypnotics, melatonin receptor agonists, antidepressants, orexin-receptor agents, and antihistamines) are usually prescribed for short-term management of the symptoms due to their side effects and long-term safety concerns, and because their benefits do not usually go beyond the cessation of the medications.[5] A variety of nonpharmacological management strategies for insomnia symptoms include behavioral treatments such as cognitive behavioral therapy for insomnia (CBT-I), physical activity, social engagement, and sleep hygiene, as well as other strategies such as bright light therapy, and acupuncture. Among these, CBT-I is considered the most effective treatment for insomnia symptoms that has superior and long-lasting effects compared to pharmacological and other nonpharmacological treatments.[5] Further, improving awareness of insomnia and poor sleep health among the general population, healthcare professionals, and policymakers is essential. Sleep health education and

promotion programs could be implemented widely or could be tailored towards more at-risk groups within the community. Healthy sleep is an important element of preventive medicine, thus it can be made part of wellness information by healthcare providers similar to regular exercise and a healthy diet.[79] Future studies could investigate the mechanistic pathways linking insomnia symptoms to healthcare services utilization.

Declarations

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Tables

Table 1. Respondent characteristics at baseline (the Health and Retirement Study, ages ≥50 years, the United States, 2002).

Respondent Characteristics	All respondents (n=13,168) Frequency (Weighted %)†, or Weighted Mean (±SD)
Time-invariant characteristics	
Sex	
Male	5,349 (42.3)
Female	7,819 (57.7)
Race and Ethnicity	
Non-Hispanic White	10,310 (83.8)
Non-Hispanic Black	1,682 (8.4)
Hispanic	923 (5.7)
Non-Hispanic Others	248 (2.1)
Level of education	
Less than high school or GED	3,488 (23.4)
High-school graduate	4,343 (32.6)
Some college	2,741 (21.8)
College and above	2,594 (22.2)
Marital status	
Married or living as married	8,499 (63.3)
Other‡	4,658 (36.7)
Whether in poverty	
Household income above the poverty threshold	12,121 (92.5)
Household income below the poverty threshold	1,047 (7.5)
Census region	
Northeast	2,137 (17.8)
Midwest	3,430 (26.4)
South	5,255 (36.4)
West	2,323 (19.4)
Time-varying characteristics	
Number of Insomnia Symptoms	
No symptoms	8,042 (61.1)
One	3,117 (23.4)
Two	1,159 (9.0)
Three	602 (4.6)
Four	246 (1.9)
Type of Insomnia Symptom§	
Difficulty initiating sleep	1,591 (11.9)
Difficulty maintaining sleep	3,322 (25.5)
Early-morning awakenings	1,581 (11.9)
Nonrestorative sleep	1,732 (13.5)
Working for pay	
Yes	4,501 (39.4)
No	8,655 (60.6)
Age (years) (range: 50–109)	66.8 (±9.4)
BMI (kg/m^2)	
Normal or underweight (<25)	4,495 (34.6)
Overweight (25–29.9)	5,049 (39.0)
Obese (≥30)	3,416 (26.4)
Comorbid medical conditions	

None	2,228 (19.2)
One	3,692 (28.3)
Two or more	7,248 (52.5)
ADL limitations	
Yes	1,910 (13.7)
No	11,255 (86.3)
IADL limitations	
Yes	1,489 (10.8)
No	11,675 (89.2)
Cognitive functioning score (range: 0–27) ¶	16.0 (±4.4)
CES-D scale score (range: 0–7)‖	1.20 (±0.03)
Often troubled with pain	
Yes	3,843 (29.4)
No	9,317 (70.6)
Covered by government health insurance plans	
Yes	8,597 (58.4)
No	4,547 (41.6)
Have at least one private health insurance plan	
Yes	9,281 (73.9)
No	3,827 (26.1)
Smoking status	
Current	1,832 (14.5)
Former	5,939 (45.3)
Never	5,303 (40.2)
Alcohol consumption	
Yes	6,226 (50.4)
No	6,941 (49.6)
Vigorous physical activity	
Yes#	5,562 (43.4)
No	7,602 (56.6)

†Weighted N= 49.6 million at the US national level.

‡Other marital statuses include separated, divorced, widowed, and never married.

§Only affirmative responses are reported to maintain table brevity

¶Higher scores indicate better cognitive performance.

‖Higher scores indicate worse depression symptoms.

#At least 1 to 3 times per month.

Abbreviations: SD, Standard Deviation; GED, General Educational Development; BMI, Body Mass Index (calculated as weight in kilograms divided by the square of height in meters); ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living; CES-D, Center for Epidemiologic Studies Depression scale.

Tables 2. Baseline characteristics of the respondents who reported at least one overnight hospital stay, nursing home stay, and home health care services utilization during the 16 years of follow-up (n=13,168, the Health and Retirement Study, 2002-2018, United States).

	Health Services Utilization at Follow-Up†		
	Overnight hospital stays (n=8.838)	Nursing home stays (n=2,173)	Home health care services (n=4,251)
Respondent Characteristics	Frequency (Weighted %), or Weighted Mean (±SD)	Frequency (Weighted %), or Weighted Mean (±SD)	Frequency (Weighted %), or Weighted Mean (±SD)
Time-invariant characteristics			
Sex			
Female	5,274 (58.0)	1,464 (67.8)	2,702 (62.1)
Race and Ethnicity			
Non-Hispanic White	6,987 (84.2)	1,818 (88.2)	3,276 (82.7)
Non-Hispanic Black	1,094 (8.2)	236 (6.9)	605 (9.7)
Hispanic	588 (5.4)	91 (3.2)	301 (5.7)
Non-Hispanic Others	167 (2.2)	28 (1.7)	68 (1.9)
Level of education			
Less than high school or GED	2,296 (23.2)	555 (23.4)	1,198 (25.6)
High-school graduate	2,930 (32.7)	746 (34.4)	1,364 (31.8)
Some college	1,896 (22.3)	482 (22.6)	934 (22.7)
College and above	1,716 (21.8)	390 (19.6)	755 (19.9)
Marital status			
Married or living as married	5,849 (64.8)	1,190 (52.2)	2,621 (59.9)
Whether in poverty			
Household income below the poverty threshold	694 (7.6)	189 (9.0)	419 (9.6)
Census region			
Northeast	1,428 (17.7)	397 (19.7)	735 (19.3)
Midwest	2,364 (27.3)	638 (30.3)	1,077 (25.9)
South	3,510 (36.1)	747 (30.4)	1,771 (37.4)
West	1,525 (18.9)	389 (19.6)	661 (17.4)
Time-varying characteristics			
Number of Insomnia Symptoms			
No symptoms	5,283 (59.7)	1,220 (56.0)	2,393 (56.0)
One	2,127 (23.7)	558 (25.2)	1,081 (25.3)
Two	828 (9.7)	223 (10.6)	450 (10.8)
Three	432 (4.9)	115 (5.4)	226 (5.5)
Four	167 (2.0)	57 (2.8)	101 (2.4)
Type of Insomnia Symptom			
Difficulty initiating sleep	1,119 (12.7)	334 (15.6)	607 (14.7)
Difficulty	2,359 (26.9)	647 (30.0)	1,243 (29.3)

maintaining sleep			
Early-morning awakenings	1,081 (12.2)	287 (14.2)	561 (13.4)
Nonrestorative sleep	1,188 (13.9)	309 (13.8)	652 (15.4)
Working for pay	3,031 (39.1)	538 (26.7)	1,308 (34.2)
Age in years	66.6 (±0.17)	70.7 (±0.21)	67.9 (±0.21)
BMI (kg/m^2)			
Normal or underweight (<25)	2,742 (31.0)	705 (32.8)	1,254 (29.4)
Overweight (25–29.9)	3,419 (39.5)	760 (35.1)	1,555 (37.1)
Obese (≥30)	2,541 (29.5)	667 (31.1)	1,363 (33.5)
Comorbid medical conditions			
None	1,271 (16.0)	218 (11.1)	459 (11.8)
One	2,418 (27.9)	516 (23.1)	1,081 (25.9)
Two or more	5,149 (56.1)	1,439 (65.8)	2,711 (62.3)
ADL limitations	1,236 (13.6)	474 (21.5)	814 (19.1)
IADL limitations	912 (10.1)	326 (15.3)	584 (13.8)
Cognitive functioning score ‡	16.2 (±0.07)	15.68 (±0.11)	15.88 (±0.09)
CES-D scale score §	1.2 (±0.03)	1.38 (±0.05)	1.38 (±0.04)
Often troubled with pain	2,797 (32.2)	797 (36.8)	1,542 (36.6)
Covered by government health insurance plans	5,894 (60.2)	1,742 (76.6)	3,090 (67.6)
Have at least one private health insurance plan	6,289 (74.1)	1,491 (70.6)	2,862 (70.0)
Smoking status			
Current	1,189 (14.2)	240 (11.6)	567 (13.7)
Former	4,061 (46.1)	1,017 (46.4)	1,951 (46.0)
Never	3,537 (39.7)	899 (42.0)	1,709 (40.3)
Alcohol consumption	4,193 (50.2)	941 (44.7)	1,917 (46.8)
Vigorous physical activity ¶	3,736 (43.5)	769 (35.8)	1,631 (38.8)

†The crude associations do not include any utilized services for those who died, dropped put, or lost to follow-up before 2004, the first wave of HSU assessment at follow-up in the current study.

‡Higher scores indicate better cognitive performance.

§Higher scores indicate worse depression symptoms.

¶At least 1 to 3 times per month.

Abbreviations: SD, Standard Deviation; GED, General Educational Development; BMI, Body Mass Index (calculated as weight in kilograms divided by the square of height in meters); ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living; CES-D, Center for Epidemiologic Studies Depression scale; HSU, Healthcare Services Utilization.

Table 3. Longitudinal associations between the time-varying number and type of insomnia symptoms and overnight hospital stays, nursing home stays, and home healthcare services utilization (n=13,168, the Health and Retirement Study, 2002-2018, United States).

	Overnight hospital stays		Nursing home stays		Home health care services	
	Adjusted OR (95% CI)†	*P*	Adjusted OR (95% CI)†	*P*	Adjusted OR (95% CI)†	*P*
Number of insomnia symptoms (ref: no symptoms)						
One	1.25 (1.19–1.31)	<.001	1.21 (1.09–1.33)	<.001	1.31 (1.22–1.40)	<.001
Two	1.40 (1.31–1.50)	<.001	1.29 (1.13–1.49)	<.001	1.52 (1.39–1.67)	<.001
Three	1.64 (1.50–1.78)	<.001	1.39 (1.17–1.67)	<.001	1.72 (1.52–1.95)	<.001
Four	1.84 (1.58–2.14)	<.001	1.54 (1.17–2.04)	<.001	1.72 (1.40–2.09)	<.001
Individual insomnia symptoms						
Difficulty initiating sleep (ref: no)	1.24 (1.16–1.32)	<.001	1.22 (1.07–1.39)	.004	1.24 (1.13–1.36)	<.001
Difficulty maintaining sleep (ref: no)	1.18 (1.12–1.23)	<.001	1.14 (1.03–1.26)	.009	1.18 (1.10–1.27)	<.001
Early-morning awakenings (ref: no)	1.07 (1.01–1.14)	.03	0.90 (0.79–1.03)	.13	1.06 (0.97–1.17)	.2
Nonrestorative sleep (ref: no)	1.26 (1.19–1.34)	<.001	1.32 (1.17–1.48)	<.001	1.34 (1.23–1.46)	<.001

Abbreviations: CI, Confidence Interval; OR, Odds Ratio; MSM, Marginal Structural Model; ref, reference.

†Stabilized final MSM weights were applied. The models incorporated a general specification for the main effect of time and were adjusted for all time-invariant “baseline-only” respondent characteristics (i.e., sex, race and ethnicity, level of education, marital status, family poverty threshold, and census region).

Supplementary Files

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