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SLEEP AND AGING (A SPIRA, SECTION EDITOR)

The Health Economics of Sleep Disorders Among Older Adults

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Abstract

Purpose of Review Sleep disorders are associated with well-documented health consequences and substantial economic burden among older adults. This review aims to highlight the existing health economic evidence of sleep disorders among older adults.

Recent Findings As highlighted throughout this review, sleep disorders are associated with substantial economic costs that are borne by patients, payers, and society. Direct and indirect costs, as well as diminished health-related quality of life, are reviewed for common sleep disorders. Further, potential health economic benefits from diagnosing and treating sleep disorders among older adults are considered.

Summary This review highlights the economic aspects of sleep disorders among older adults, including the economic costs of treating sleep disorders and potential economic gain from treating sleep disorders. Future research should seek to include and incorporate economic endpoints into studies of sleep among older adults. Particular emphasis should be placed on older adults with comorbid medical and psychiatric disease (e.g., cardiovascular disease, depression, neurodegenerative disorders including Alzheimer's disease), as well as the relative economic impact of various approaches to diagnosis and treatment, including telemedicine and remote monitoring of sleep among older adults.

Keywords Sleep economics · Cost of apnea · Cost of insomnia · Health-related quality of life (HRQoL) · Health economics and outcomes

Introduction

Sleep complaints increase with age, and a substantial body of evidence highlights the adverse health consequences of clinical sleep disorders among older adults. For example, poor sleep is associated with increased risk for cardiovascular [1–3] and cerebrovascular events [4], endocrine dysfunction [5], neurodegenerative diseases including Alzheimer's disease [5, 6], as well as psychiatric [7, 8], and other chronic conditions [7, 9••, 10] among older adults. Beyond these well-documented health consequences, sleep disorders are also associated with substantial economic burden among older adults, with costs borne by patients, payers, and society.

The purpose of this review is to highlight the health economic aspects of sleep disorders among older adults. First, we present an overview of health economic measurement. Next, we review economic burden associated with untreated sleep disorders, followed by discussion of potential economic benefit from sleep disorder treatments among older adults. Finally, we discuss directions for future research, as well as policy implications.

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Measuring Economic Impact

Previous economic studies have estimated and calculated the costs associated with insufficient sleep among the general population [11, 12]. These costs include both direct costs and indirect costs of sleep-related disorders [13, 14]. The direct costs of sleep disorders include expenditures associated with the diagnosis and treatment of these disorders, such as inpatient and outpatient encounters and procedures, prescriptions, and other treatment costs, as well as transportation to

and from disorder-related treatment. Indirect costs, which are incurred outside the direct pathway of clinical care, are not directly attributable to disease-specific diagnosis or treatment. Examples include the costs of non-disorder-specific healthcare utilization (HCU) or exacerbated HCU due to a sleep-related comorbidity, lost workplace productivity (i.e., absenteeism or presenteeism, wherein employees are physically present but perform at reduced productivity), as well as costs associated with increased accident risk or other vulnerabilities.

In addition to direct and indirect costs associated with insufficient sleep, another important economic outcome is the quality-adjusted life year (QALY) [13, 14]. QALYs are a health economic metric intended to standardize the adverse impact of disease on patient health-related quality of life (HRQoL). QALYs incorporate both quality of life and time (i.e., [quality on 0–1 utility scale] * [time in years]) and provide researchers a standardized metric to compare the economic impact and burden of disease across multiple diseases [9••], as well as to evaluate the economic impact of treatment in cost-effectiveness studies [15].

Economic Impact of Untreated Sleep Disorders

Obstructive Sleep Apnea

Multiple studies spanning over two decades demonstrate that untreated obstructive sleep apnea (OSA) is associated with greater utilization of healthcare services (i.e., healthcare utilization [HCU]) as well as higher healthcare costs among older adults (see Table 1). For example, in two separate reports of prospective case-control studies based in Israel, Tarasiuk et al. reported [19] that older adults diagnosed with OSA had significantly higher HCU and costs as compared to healthy controls. Among OSA patients > 65 years of age and relative to non-OSA controls, OSA was associated with 2.2-fold greater HCU. Similarly, this same group [20] reported on a subsample of older adults (n = 158) included in a larger study examining the costs of OSA. Healthcare costs 2 years before diagnosis were over 1.8 times as high for older adult patients with OSA, relative to non-OSA controls. Further, results suggested OSA-related costs increase with age, as they were 1.9 times higher among older adults with OSA than costs among middle-aged adults with OSA.

Several retrospective cohort studies have also assessed the economic impact of untreated OSA among older adults. In a 2014 study from the USA, Diaz and colleagues reported [17] that relative to chronic OSA and no OSA, newly diagnosed OSA was associated with increased emergency department (ED) visits (32%, 15%, and 37%, respectively). Similarly, relative to chronic OSA and no OSA, newly diagnosed OSA was associated with increased risk for hospitalization (17%, 7%, and 24%, respectively). In a study of US adults > 60 years with OSA (n = 750,851), Gamaldo and colleagues [18] found that the prevalence of OSA had increased significantly over time (from 1.47 in 2006 to 5.01 in 2012). Concurrently, total costs for OSA-related hospital admission increased during this same period, from 22,250 US dollars (USD) in 2002 to 31,527USD in 2012. More recently, Wickwire and colleagues [23] analyzed data from a random 5% sample of Medicare administrative claims for years 2006–2013 (N = 287,191), which included 10,317 patients with OSA (M age = 75.9 years, 35.6% male). During the year prior to OSA diagnosis and relative to matched non-sleep disordered controls, beneficiaries with OSA demonstrated increased HCU and higher total annual costs across all points of service (19,566USD), with the greatest marginal increase in inpatient care (15,482USD) and the lowest marginal increase in prescriptions (431USD). Another recently published study from the USA reports [16] on a separate 5% cohort of Medicare beneficiaries. Of 22,361 beneficiaries with at least one claim for OSA (M age = 67.2), sleep apnea was significantly associated with higher costs (OR = 1.60; 95%, CI = 1.58, 1.63) compared to those without sleep apnea.

OSA also increases costs by worsening outcomes in comorbid conditions. A 2016 study [21] from the USA included 184,217 older patients with end-stage renal disease (ESRD), of whom 15,121 had OSA (M age = 77 years, 54% male). Patients diagnosed with sleep disordered breathing (SDB) were younger, had more non-nephrology clinic visits, had higher body mass index, and had more comorbidity. However, the diagnosis of OSA was associated with lower risks of death, myocardial infarction, and ischemic stroke, highlighting the multifactorial nature and methodological challenges to studying complex disease comorbidities.

Insomnia

Untreated insomnia is associated with increased HCU and costs among older adults (see Table 2). As in the case of OSA, the majority of economic studies of insomnia have a retrospective cohort design. For example, Ozminkowski and colleagues [26] performed a seminal study that included 75,558 US older adults with insomnia (M age = 75 years) and found that relative to age and gender-matched controls, older adults with insomnia incurred increased direct costs of 1143USD over 6 months. Similarly, Gamaldo and colleagues [18] analyzed data from a large, US-based cohort (N = 35,258,031, all > 60 years, M age = 75 years) and found that total per annum costs for insomnia-related hospital admissions

Table 1 Economic studies of obstructive sleep apnea (OSA) among older adults

Year authors, reference	Sample (location, N, age [years], % male)	Particular comorbidity	Study design	OSA measure	Economic outcome	Main findings
2019 Chhatre, Chang, et al. [16]	USA $N = 435,011$ of which 22,361 had a claim for sleep apnea diagnosis 67.2 53	Various comorbidities	Retrospective cohort of a 5% sample of Medicare administrative data for years 2006–2010	Claim for sleep apnea diagnosis between 2007 and 2008 and without a claim for sleep apnea in 2006	Total cost was sum of reimbursements for inpatient, outpatient, durable medical equipment, provider, home health agency, and hospice within 2 years post-index date	Sleep apnea was associated with higher costs (OR = 1.60) compared to those without sleep apnea
2014 Diaz, Faverio, et al. [17]	USA 1,867,876 older adult veterans having 2 years of care, 82,178 (4.4%) with OSA. 74 98.3	Various comorbidities	Retrospective cohort study of VA data	Inpatient and outpatient VHA data using ICD-9 codes for OSA during the fiscal years 2003–2005	Emergency department (ED) visits and hospitalizations	OSA patients were younger and more likely to have chronic diseases than those without OSA. The proportion of patients with new OSA diagnosis who required at least one ED visit was higher than the proportion of chronic OSA and no OSA patients (37%, 32%, and 15%, respectively). The proportion of new OSA patients who required at least one hospitalization was also higher than the proportion of chronic OSA and no OSA patients (24%, 17%, and 7%, respectively)
2016 Gamaldo, Beydoun, et al. [18]	USA 35,258,031 75.37 41.5	Subgroup analysis various comorbidities	Retrospective cohort	ICD9 CM	Mortality risk (MR), length of stay (LOS), and total charges (TC)	750,851(2.13%) had OSA and 21,810 (0.06%) had OSD. OSA rates increased significantly over time (1.47 in 2006 to 5.01 in 2012). TC(2012$) for OSA-related hospital admission increased over time from $22,250 in 2002 to $31,527 in 2012
2005 Tarasiuk, Greenberg-Dotan, et al. [19]	Israel 218 patients with OSAS and 1:1 matched control subjects from the general population 54.8 79.8	Hypertension, ischemic heart disease, diabetes mellitus, and pulmonary disease	Case-control prospective study	OSAS patients diagnosed through nocturnal polysomnography studies	Indexes of healthcare utilization 2 years prior to the polysomnography	Compared to healthy controls, healthcare utilization was 1.7-fold higher in the OSAS patients due to more hospitalization days, consultations, and cost. Age > 65 was the leading element predicting the most costly OSAS patients (odds ratio [OR] 2.2). OSAS patients < 65 years consumed 2.2-fold more healthcare resources than control subjects. The upper 25% ($n = 55$) of OSAS patients with the highest utilization consumed sevenfold more healthcare resources than the lower 75% of the patients
2008 Tarasiuk, Greenberg-Dotan, et al. [20]	Israel 158 older adult and 1166 middle-aged (aged 67–89 and 40–64, respectively) patients with OSA 56.71 60	Arthropathy, asthma, CVD, diabetes mellitus, hyperlipidemia, hypertension, hypothyroidism, reflux, esophagitis, and gastritis End-stage renal disease	Case-control prospective study	Polysomnography by primary care physicians	All costs combined. Indicators of healthcare utilization: hospitalization, emergency department visits, visits to specialists, and prescriptions	Healthcare costs 2 years before diagnosis were more than 1.8 times as high for older adult patients with OSA as for healthy controls. Expenditures of older adult patients with OSA were 1.9 times as high as for middle-aged patients with OSA

Table 1 (continued)

Year authors, reference	Sample (location, N, age [years], % male)	Particular comorbidity	Study design	OSA measure	Economic outcome	Main findings
2016 Tuohy, Montez-Rath, et al. [21]	USA 184,217 older patients developed ESRD, of whom 15,121 had sleep disordered breathing (SDB) 77 53.2		Retrospective cohort	ICD-9 from Medicaid billing	All-cause mortality, incident myocardial infarction, ischemic stroke, and atrial fibrillation	SDB was associated with higher risk of death and atrial fibrillation as compared with other patients with ESRD, but not associated with myocardial infarction or ischemic stroke risk. After further adjustment for all baseline characteristics, diagnosed SDB was associated with slightly lower risks of death (hazard ratio [HR]: 0.93), myocardial infarction (HR: 0.92), and ischemic stroke (HR: 0.90)
2019 Wickwire, Tom, et al. [22]	USA ($N = 287{,}191$) included 10,317 beneficiaries with OSA and 276,874 non-sleep disordered controls 75.9 35.6	Various comorbidities	Retrospective cohort of a 5% sample of Medicare administrative data for years 2006–2013	ICD-9 CM or initiation of OSA treatment with either CPAP or oral appliance therapy	Healthcare utilization and costs from inpatient, emergency department, outpatient, and prescriptions services	During the year prior to OSA diagnosis and relative to matched non-sleep disordered controls, beneficiaries with OSA had increased HCU and higher total annual costs across all points of service ($19,566). Inpatient care was associated with the highest marginal costs ($15,482)

increased over time, from 22,250USD in 2002 to 31,527USD in 2012.

Like OSA, insomnia also increases costs by worsening outcomes in comorbid disease states. For example, among older adults with depression and relative to those with depression alone, individuals with comorbid depression and insomnia (n = 2756; M age = 75.6 years) have been found to have more total outpatient visits (8.34 vs 7.26), depression-related encounters (3.9 vs 2.1), antidepressant prescriptions (5.0 vs 4.2), and greater healthcare costs (1007USD) over a 1-year period [24]. Similarly, Kaufmann and colleagues reported [25] on a US-based study of 14,355 middle-aged and older adult patients (M age = 55) with hypertension (38%), osteoarthritis (38%), and diabetes (21%). Relative to participants without insomnia symptoms, those patients reporting one or more symptoms of insomnia had greater odds of self-reported hospitalization (adjusted odds ratio [AOR] = 1.28), use of home healthcare services (AOR = 1.29), and any health service use (AOR = 1.28) over a 1-year period. Those reporting two or more insomnia symptoms had even greater odds of hospitalization (AOR = 1.71), use of home healthcare services (AOR = 1.64), and any health service use (AOR = 1.72) over this same period.

More recently, Wickwire and colleagues reported the results of two US-based cohort studies examining economic aspects of insomnia [22••] and insomnia treatment [27] among older adult Medicare beneficiaries in the USA. Using a random 5% sample of Medicare claims data and relative to age- and gender-matched non-insomnia controls, our group found [22••] that each beneficiary with insomnia (n = 151,668, M age = 70.6 years) demonstrated an average of 63,607 (USD 2013) higher annual all-cause costs. These were driven primarily by inpatient costs (60,900USD), as well as elevated ED costs (1492USD) and prescription costs (486USD) over the 12 months prior to insomnia diagnosis. In a second study derived from the same 5% sample, beneficiaries with insomnia (n = 23,079, M age = 71.7 years) [27] demonstrated increasing costs and HCU during the 12 months prior to insomnia diagnosis. Further, beneficiaries who received insomnia medication treatment (n = 5154) [28] also demonstrated increased ED visits and prescription fills in the year following insomnia diagnosis. After accounting for pre-diagnosis differences between groups, treated and untreated individuals displayed no significant differences in pre- to post-diagnosis costs. Additional important findings from these analyses which are that of a minority (22%) of Medicare beneficiaries diagnosed with insomnia received an FDA-approved insomnia medication, and significant differences exist between individuals who do and do not receive treatment [27]. From a health economic perspective, it is vital to understand why some individuals are treated but others are not, so that the right treatments can be delivered to the right individuals at the right times.

Table 2 Economic studies of Insomnia among older adults

Year authors reference	Sample (location, N, age [years], % male)	Particular comorbidity	Study design	Insomnia measure	Economic outcome	Main findings
2010 Asche, Joice, et al. [24]	USA 2756 75.6 26	Depression (MDD)	Retrospective cohort	ICD 9 code	Costs, total direct costs, MDD costs, days with outpatient visits, days in inpatient stay, MDD-related utilization, MDD visits, antidepressant prescription fills, antidepressant days	Insomniacs with MDD had more outpatient visits 8.34 vs non-insomniacs with MDD 7.26; MDD-related visits 3.9 vs 2.1; and antidepressant prescriptions 5.0 vs 4.2. Direct costs for insomniacs with MDD were higher than non-insomniacs with MDD ($4858 vs $4007)
2016 Gamaldo, Beydoun, et al. [18]	USA 35,258,031 75.37 41.5	Various comorbidities	Retrospective cohort	ICD9 CM	Mortality risk(MR), length of stay(LOS), and total charges(TC)	About 0.75% had insomnia. Insomnia rates increased (0.27% in 2002 to 1.29 in 2012). TC (2012$) for insomnia-related hospital admission increased over time from $22,250 in 2002 to $31,527 in 2012; while LOS and MR both decreased. Comorbidities such as depression, cardiovascular risk factors, and neurological disorders steadily increased over time in patients with sleep disturbances
2013 Kaufmann, Canham, et al. [25]	USA 14355 all > 55 45	59% Hypertension, 38% osteoarthritis, and 21% diabetes	Longitudinal retrospective cohort	The presence of 1, 2, or more self-reported insomnia symptoms in 2006	Self-reported utilization in the past 2 years (hospitalized, used home healthcare services or placement in a nursing home)	Compared with respondents reporting no insomnia symptoms, those reporting one symptom had greater odds of hospitalization (adjusted odds ratio [AOR] = 1.28), use of home healthcare services (AOR = 1.29), and any health service use (AOR = 1.28). Those reporting two or more insomnia symptoms had greater odds of hospitalization (AOR = 1.71), use of home healthcare services (AOR = 1.64), nursing home use (AOR = 1.45), and any health service use (AOR = 1.72)
2007 Ozminkowski, Wang, Walsh [26]	USA 75,558 75 39	Charlson comorbidity index and number of psychiatric diagnoses	Retrospective cohort	ICD9 CM codes or the onset of prescription treatment for insomnia	Direct costs included inpatient, outpatient, pharmacy, and emergency room costs for all diseases, for 6 months before an index date. Indirect costs included costs related to absenteeism from work and use of disability programs	Direct and indirect costs were $1143 greater for insomnia patients
2019 Wickwire, Tom, et al. [22]	USA 151,668 70.6 37.2	Various comorbidities	Retrospective cohort of a 5% sample of Medicare administrative data for years 2006–2013	Claim based on ICD9 CM codes or prescription fill for an insomnia-medication	Healthcare utilization (HCU) and costs from inpatient, emergency department (ED), outpatient, and prescriptions services	Rates of HCU were highest for inpatient care (rate ratio [RR] 1.61) and lowest for prescription fills (RR 1.17). Beneficiaries with insomnia demonstrated $63,607 higher all-cause costs, driven primarily by inpatient care ($60,900) ED ($1492) and prescription costs ($486) which were elevated among cases relative to controls

Table 3 Economic studies of restless leg syndrome (RLS) and other sleep disorders among older adults

Year authors reference	Sample (location, N, age [years], % male)	Study design	RLS and other measure	Economic outcome	Main findings
2010 Dodel, Happe, Peglau et al. [30]	Germany 519 65.2 37.2	Retrospective cohort	International RLS severity scale (IRLS)	Direct and indirect RLS costs were examined from different perspectives including a societal perspective, the individual patient perspective, as well as the payer (insurance system) perspectives. HRQoL was measured through VAS method	Average total costs were 2090 EUR for this period. The average direct medical and nonmedical costs from the perspective of the health insurance provider were determined to be 780 EUR, with 300 EUR attributed to drug costs and 354 EUR to hospitalization costs. Average total indirect costs amounted to 1308 EUR and were calculated based on productivity loss, using the human capital approach. Health-related quality of life was determined to be substantially affected by RLS; the mean EQ-5D visual analogue scale (VAS) was 55.6, considerably lower than that of the age-matched general population
2007 Kushida, Martin, Nikam et al. [31]	USA 187 53.25 37	Retrospective cohort	Screening survey of RLS symptoms	HRQoL	All SF-36 measures were significantly below adjusted US general population norms. Five of the eight scales (physical functioning, role physical, bodily pain, general health, vitality) were below US norms by 0.8 or more standard deviations (SD), while the remaining three (social functioning, role emotional, mental health) were 0.5 SD below norm. The burden of RLS was greater on physical than on mental/emotional HRQoL (physical and mental summary scores were 1.08 and 0.40 SD below norm, respectively), and greater than that observed for type-2 diabetes
2018 Lubetkin and Jia [9]	USA 2380 73.6 43.9	Retrospective cohort	Sleep duration reported in NHANES survey	HRQoL	More than one third of participants reported a suboptimal sleep duration. Short sleep duration had a greater adverse impact on morbidity, with reductions in HRQoL, while long sleep duration had a greater adverse impact on mortality. Compared to participants who reported between 7 and 9 h of sleep per night, mean QALYs were significantly lower among participants who slept 10 or more hours a night (7.8 QALY; decrease of 9.8 QALY)

Table 4 Economic studies of treatments of obstructive sleep apnea (OSA) among older adults

Year authors reference	Sample (location, N, age [years], % male)	Particular comorbidity	Study design	OSA treatment	Economic outcome	Main findings
2019 Chhatre, Chang, et al. [16]	USA 435,011 which 22,361 had OSA diagnosis claim 67.2 53	Various comorbidities	Retrospective cohort of a 5% sample of Medicare administrative data for years 2006–2010	Treatment adherence	Total cost was sum of inpatient, outpatient, durable medical equipment, provider, home health agency, and hospice costs within 2 years post-index date	Half of those with sleep apnea received CPAP treatment. Longitudinal analysis showed post-level increase in mean monthly cost for all CPAP adherence groups and no-CPAP group. However, the increase was smallest for the full CPAP adherence group. Full CPAP adherence was associated with lower change in cost (OR = 0.92) compared to the no-CPAP group
2011 Javaheri [32]	USA 30719 67.1 43	Not reported	Retrospective cohort	CPAP	Costs	Costs were lowest for those tested, diagnosed, and treated ($6465/quarter [$5758 in 2010]) and highest for those not tested, clinically diagnosed, and not treated ($12,080/quarter [$10,759 in 2010])
2014 McMillan et al. [33]	UK 278 71 79	Accident occurrence	Multicenter RCT	APAP	CEA HRQoL: EQ-5D and SF-6D	PAP was associated with 0.018 SF-6D QALYS gained. EQ-5D QALYs were similar between groups. PAP reduced costs (−$61 [−£35 in 2014 GBP]) over 1 year and was marginally cost-effective. No significant difference in accident costs
2011 Tripathi [34]	USA 2194 NR 60.2	Cerebrovascular events	Retrospective cohort	Treatment adherence (TA)	Costs	TA associated with reduced outpatient visits for OSA, cerebrovascular events, and mean acute service costs

Table 5 Economic studies of treatments of insomnia among older adults

Year authors reference	Sample (location, N, age [years], % male)	Study design	Insomnia treatment	Economic outcome	Main findings
2015 Tannenbaum, Diaby, et al. [35]	US hypothetical cohort of Medicare beneficiaries suffering from insomnia hypothetical cohort of > 65-year hypothetical cohort of Medicare gender ratios	Decision tree simulation	All patients presumed (hypothesized) to have insomnia and treated through cognitive behavioral therapy (CBT) or sedative-hypnotics	The main outcome measure was the incremental cost per quality-adjusted life year (QALY) gained	On an annual basis, CBT showed dominance (cost: US$19,442; QALYs: 0.594) over sedative-hypnotics (cost: US$32,452; QALYs: 0.552) and no treatment (cost: US$33,853; QALYs: 0.517). The net monetary benefit was positive for CBT (US$10,287) and negative for sedative-hypnotics (-US$4851) and no treatment (-US$7993)
2019 Wickwire, Vadlamani et al. [27]	USA 23079 (5154 treated) 71.7 29.3	Retrospective cohort: longitudinal difference in difference	Treated patients with ICD 9 diagnostic code	HCU and costs	For both treated and untreated individuals, HCU and costs increased during the 12 months prior to diagnosis. Insomnia treatment was associated with significantly increased ED visits and prescription fills in the year following insomnia diagnosis. After accounting for pre-diagnosis differences between groups, no significant differences in pre- to post-diagnosis costs were observed between treated and untreated individuals

Restless Legs Syndrome and Sleep Duration

Restless legs syndrome (RLS) is common and associated with adverse health consequences among older adults [28, 29]. However, very few studies have evaluated health economic aspects of RLS [30, 31] (see Table 3). A study of RLS patients ($N = 519$, M age = 65.2 years) assessed in an ambulatory care setting in Germany [30] reported mean annual total costs attributable to RLS which were 2090 Euros (EUR). This included direct costs (780 EUR, with 300 EUR attributed to drug costs and 354 EUR to hospitalization costs), as well as indirect costs of 1308 EUR based on productivity loss. A second study reported the health burden of RLS in terms of HRQoL but did not present detailed economic results [31].

Although we did not find studies of the economic impact of other sleep disorders besides OSA, insomnia, and RLS, we did find a 2018 analysis of older adults ($N = 2380$ age = 73.6 years) from the US-based National Health and Nutrition Examination Survey (NHANES), by Lubetkin and Jia [9••] who evaluated the impact of sleep duration on HRQoL. The authors found that relative to participants who reported between 7 and 9 h of sleep per night (17.6 QALY), mean lifetime QALYs were significantly lower among participants who slept 10 or more hours a night (7.8 QALY; decrease of 9.8 QALY) and those who slept less than 6 h per night (15.4 QALY; decrease of 2.2 QALY). Interestingly, long sleep (in excess of 10 h) was associated with increased mortality (i.e., reduction in life years), whereas short sleep (> 7 h) was associated with increased morbidity (i.e., reduction of HRQoL), suggesting different mechanisms for economic impact of short and long sleep duration.

Economic Impact of Sleep Disorder Treatments

Obstructive Sleep Apnea Treatments

Relative to burden of disease studies, fewer studies have considered the economic impact of OSA treatments among older adults. Nonetheless, preliminary evidence suggests that OSA treatments are associated with positive economic results among older adults (see Table 4). For example, McMillan and colleagues [33] conducted a multicenter randomized clinical trial in the UK to evaluate the impact of OSA treatments among older adults with OSA ($N = 278$). Relative to supportive care alone, positive airway pressure (PAP) treatment was associated with 0.018 QALYS gained and reductions in overall healthcare costs of 61USD [35GBP (2014)] over 12 months. They found that relative to supportive care, PAP was marginally cost-effective. Javaheri and colleagues [32] conducted a retrospective cohort study of 30,719 Medicare beneficiaries with OSA (aged 67.1 year to 76.5 year) and

Table 6 Recommendations to advance health economic studies of sleep disorders among older adults

Domain	Recommendation
Include health economic endpoints	Include measures of direct and indirect costs of sleep disorders in all future trials of older adults
Advance research on health utility losses for all sleep disorders	Availability of health-related quality of life (HRQoL) utility loss measures for all sleep and circadian rhythm disorders included in the ICD
Evaluate cost-effectiveness	Include measures of both general and disease-specific measures of health-related quality of life in all future sleep disorder trials of older adults
Study-specific populations	Conduct health economic analyses among older adult women, among different ethnic groups, and among older adult patients with varying severities of sleep disorders
Understand comorbid sleep disorders	Study economic impact of insufficient sleep and its treatments in costly and chronic comorbid disease states such as heart failure, type 2 diabetes mellitus, and depression
Increase adherence	Study economic cost-benefit of interventions designed to increase treatment adherence, including cognitive behavioral treatment, telehealth and remote monitoring, automated approaches, and other interventions
Adopt employer perspective	Evaluate cost-benefit of insufficient sleep treatments from the perspective of the employers of older adults: impact on lost workplace productivity (e.g., absenteeism) and workplace accident and injury risk
Evaluate global impact	Evaluate cost-effectiveness of treating insufficient sleep worldwide in various healthcare delivery systems
Compare economic effectiveness	Compare economic effectiveness between the treatments of insufficient sleep to empower stakeholders to make evidence-based decisions regarding allocation of scarce healthcare resources

found that costs were lowest among those tested, diagnosed with OSA, and treated (5758USD in 2010), while overall costs were highest for those not tested, clinically diagnosed, and not treated (10,759USD in 2010). Similarly, Tripathi and colleagues [34] found that relative to non-adherence, PAP adherence was associated with reduced outpatient visits for OSA and cerebrovascular events, as well as lower mean acute service costs. A recently published study from the USA [16] reports that among Medicare beneficiaries with OSA (n = 22,361, M age = 67.2), only half received CPAP treatment. Using an interrupted time series analysis, these authors found that post-treatment increases in mean monthly cost were lowest for the full CPAP adherence group, compared to the no-CPAP group (OR = 0.92).

Insomnia Treatments

Two studies have evaluated the impact of insomnia treatments among older adults (see Table 5). Wickwire and colleagues [27] conducted a longitudinal retrospective cohort study among a cohort of 23,079 Medicare beneficiaries with insomnia (M age = 71.7 years), of whom 5154 were treated with FDA-approved medication therapies. Using a longitudinal difference in difference approach to control for baseline differences between groups, insomnia treatment was associated with significantly increased ED visits and prescription fills in the year following insomnia diagnosis. However, after accounting for pre-diagnosis differences between groups, the differences in post-diagnosis costs between treated and untreated individuals were not significant. Tannenbaum and colleagues [35] conducted an economic modeling study to simulate a hypothetical prospective cohort of Medicare beneficiaries suffering from insomnia and to compare the economic impact of cognitive behavioral therapy for insomnia (CBTI) with medication therapy and no treatment. In terms of economic benefit, CBTI (cost: 19,442USD; QALYs: 0.594) was found superior to sedative-hypnotics (cost: 32,452USD; QALYs: 0.552) and no treatment (cost: 33,853USD; QALYs: 0.517). The net monetary benefit was positive for CBTI (10,287USD) and negative for sedative-hypnotics (−4851USD).

Future Directions

As evidenced throughout this review, multiple studies demonstrate an increased economic burden associated with the most common sleep disorders among older adults (i.e., OSA and insomnia), as well as RLS and

insufficient sleep. However, extant studies are relatively few in number and have employed various, most often retrospective, study designs. Few analyses have considered important subpopulations, such as "young old" or "old old," as well as those with important disease comorbidities (e.g., Alzheimer's disease and related dementias). At the same time, despite the increased prevalence of sleep disorders among older adults as well as the herein reviewed associated costs, very few studies have considered potential economic benefit from sleep disorder treatments. Thus, our most important recommendation for future research is to include economic endpoints in all studies of sleep disorders among older adults. Furthermore, health utility measures, which are the basis for calculating HRQoL, only exist for the most studied sleep disorders, namely, OSA, insomnia, and RLS. These utility measures should become available for all sleep disorders included in the International Classification of Disease, including those related to circadian disorders. Once they become available, researchers can use them to evaluate cost-effectiveness of treatments and other interventions. Table 6 summarizes other specific actionable recommendations. A rational health policy requires the spending of economic and monetary resources to prolong and advance the quality of human life. Targeting sleep disorders (and sleep health more broadly) may also lead to cost savings.

Conclusions

Sleep disorders are common among older adults and are associated with numerous adverse health consequences, including diminished quality of life. In addition, as highlighted throughout this review, sleep disorders are also associated with substantial economic costs that are borne by patients, payers, and society. Although much remains to be learned, emerging evidence suggests potential economic health benefits from diagnosing and treating sleep disorders among older adults. Future research should seek to evaluate the economic impact of insufficient and disturbed sleep within various subpopulations of older adults, including those with comorbid medical and psychiatric disease (e.g., cardiovascular disease, depression, neurodegenerative disorders including Alzheimer's disease), as well as the relative economic impact of various approaches to diagnosis and treatment, including telemedicine and remote monitoring of sleep among older adults.

Author's Contribution EMW has served as a scientific consultant for Dayzz, Eisai, Merck, and Purdue and is an equity shareholder in WellTap.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest. Dr. Wickwire reports grants from AASM Foundation, grants from Department of Defense, grants from Merck, grants from ResMed, personal fees from Dayzz, personal fees from Eisai, personal fees from Merck, personal fees from Purdue, and his role as an equity shareholder at WellTap, outside the submitted work. EMW's institution has received research funding from the AASM Foundation, Department of Defense, Merck, and ResMed.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

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