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ORIGINAL ARTICLE

# Self-reported poor sleep on multiple dimensions is associated with higher total health care costs in older men

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## Abstract

**Study Objectives:** To estimate the association of self-reported poor sleep in multiple dimensions with health care costs in older men.

**Methods:** Participants were 1,413 men (mean [SD] age 76.5 [5.7] years) enrolled in both the Outcomes of Sleep Disorders in Older Men (MrOS Sleep) study and Medicare Fee-for-Service. Poor sleep was characterized at the baseline MrOS Sleep visit on five dimensions (satisfaction, daytime sleepiness, timing, latency, and duration). Health care costs and utilization were ascertained over 3 years of follow-up using Medicare Claims.

**Results:** Median (interquartile range [IQR]) annualized total health care costs (2018 US dollars) rose from \$3,616 (IQR 1,523–7,875) for those with no impaired sleep dimensions to \$4,416 (IQR 1,854–11,343) for men with two impaired sleep dimensions and \$5,819 (IQR 1,936–15,569) for those with at least three impaired sleep dimensions. After multivariable adjustment, the ratio of total health care costs (CR) was significantly higher for men with two (1.24, 95% confidence interval [CI] 1.03– to 1.48) and men with at least three impaired sleep dimensions (1.78, 95% CI 1.42 to 2.23) vs. those with no impaired sleep dimensions. After excluding 101 men who died during the 3-year follow-up period, these associations were attenuated and not significant (CR 1.22, 95% CI 0.98 to 1.53 for men  $\geq 3$  impaired sleep dimensions vs. none).

**Conclusions:** Self-reported poor sleep on multiple dimensions is associated with higher subsequent total health care costs in older men, but this may be due to higher mortality and increased health care costs toward the end of life among those with poor sleep health.

## Statement of Significance

Previous studies of the association of sleep with health care costs have not focused on the older population, among whom sleep complaints are most common and health care costs highest. Using a dataset of community-dwelling older men age >70 years linked to Medicare claims, we found that poor self-reported sleep on multiple dimensions is associated with higher total health care costs, independent of comorbid chronic medical illnesses, functional limitations, depressive symptoms, and other confounders. However, this association was attenuated and no longer significant when men who died during the 3-year follow-up period were excluded. Further research is needed to determine if the association is causal or attributable to confounding variables also associated with mortality.

**Key words:** aging; poor sleep; health care costs; health care utilization; mortality

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## Introduction

Inadequate sleep several times per week is reported in 33% or more of adults [1, 2], and the prevalence of self-reported sleep disturbance increases with age [2]. Disordered sleep has been associated with many aspects of poor health in older adults. These include a variety of prevalent chronic diseases [3] as well as a higher risk of incident cardiovascular disease [4–6], diabetes mellitus [7], depression [8–10], decline of physical function and capability [11], cognitive impairment [12–14], reduced quality of life [15, 16], increased risk of falls [17, 18], and mortality [19–22].

Both self-reported and objectively measured sleep disorders have been associated with substantial societal costs [16, 23] and increased health care costs [3, 24–31]. However, in the majority of these studies, disordered sleep has been characterized as either a specific sleep disorder (such as obstructive sleep apnea) or a diagnosis of insomnia. Moreover, these studies have not been specifically focused on the population older than age 65 years. Older adults have a high prevalence of sleep complaints, comorbid medical conditions, and impaired functional status, and the aged population accounts for the majority of health care expenditures. It is unclear if the associations of impaired sleep with health care costs are at least in part due to accompanying comorbid illness, functional capacity impairment, depressive symptoms, and/or cognitive impairment. Moreover, since poor sleep is associated with an increased risk of mortality and because health care costs are particularly high in the last 6 months of life [32, 33], it is plausible poor sleep may be a marker of limited life expectancy with its attendant high health care utilization close to death, rather than a true cause of high health care costs.

Sleep health is increasingly viewed as a multidimensional construct important for maintenance of well-being, quality of life, robust mental and physical functioning, and longevity, independent of specific comorbid medical conditions and other characteristics that affect health outcomes [34–38]. Buysse [38] has characterized five dimensions of sleep health that each is associated with prevalent and incident comorbid illness and mortality, including satisfaction with sleep, daytime alertness, sleep timing (when in the 24-hour day does sleep occur), sleep latency (how long does it take to fall asleep), and sleep duration (total hours spent asleep). These self-reported sleep health dimensions are assessed by the SATED scale. Impairment on any one of these dimensions is not specific to any sleep disorder. In a cohort of older women enrolled in the Study of Osteoporotic Fractures (SOF), poor sleep in these dimensions was associated with higher total health care costs, but this association was explained in large part by a higher prevalence of comorbid medical conditions, functional limitations, and depressive symptoms among those women with poor multidimensional sleep health. However, the association of multidimensional impaired sleep health with health care utilization and costs in older men is uncertain.

Our primary objective was to estimate the association of impaired multidimensional sleep health with subsequent health care costs and utilization in community-dwelling older men, after accounting for traditional indicators, including comorbid medical conditions, functional limitations, depressive symptoms, and cognitive impairment.

## Methods

Between 2000 and 2002, the Osteoporotic Fractures in Men (MrOS) study enrolled 5,994 community-dwelling ambulatory men aged 65 years and older at six geographic sites in the United States (Birmingham, AL; Minneapolis, MN; Palo Alto, CA; Pittsburgh, PA; Portland, OR; and San Diego, CA), as described in previous publications [39, 40], after Institutional Review Board (IRB) approval for all participating institutions. All men provided written informed consent.

Between December 2003 and March 2005, 3,135 of these men were also enrolled in the Outcomes of Sleep Disorders in Older Men (MrOS Sleep) ancillary study. Men were screened for nightly use of mechanical devices during sleep, including pressure mask for sleep apnea (continuous positive airway pressure [CPAP] or bilevel positive airway pressure [BiPAP]), mouthpiece for snoring or sleep apnea, or oxygen therapy, and were excluded if they could not forgo use of these devices during an overnight PSG recording. Men with a tracheotomy were also excluded. For these analyses, 28 additional men were excluded because of missing covariate data (Figure 1).

Of the remaining 3,107 men, the analytic cohort for these analyses were 1,413 men enrolled in Medicare Fee-for-Service (FFS) both parts A and B from the date of their first MrOS Sleep visit through the third anniversary of that visit (or until death within this period). Those enrolled in Medicare Advantage (1,694 men) were excluded because their health care costs and utilization are not fully observable in available Medicare Claims Data (Figure 1). Characteristics of men included in the analytical cohort were similar to those men excluded due to enrollment in a Medicare Advantage plan (Supplementary Table S1), except that excluded men were slightly more likely to be nonwhite and to have a high school education or less.

### Self-reported multidimensional sleep health

At the first MrOS Sleep visit, participants were asked the following five questions: (1) on most nights, how many hours do you sleep each night?; (2) how many hours of sleep do you need each night to feel rested?; (3) during the past month, what time have you usually gone to bed at night?; (4) during the past month, when have you usually gotten up in the morning?; and (5) during the past month, how long (in minutes) has it usually taken you to fall asleep each night? Participants also completed the Epworth Sleepiness Scale (ESS), a self-administered questionnaire that assesses daytime sleepiness [41, 42].

Men who reported that their hours of actual sleep were less than what they needed to feel well rested were scored as “poor” on the dimension of sleep satisfaction. Men who scored >10 on the ESS were scored as “poor” on daytime alertness [41, 42]. Mid-sleep time was assessed by identifying the clock time halfway between falling asleep time and waking up time. Mid-sleep time was categorized based on octiles of the mid-sleep time; men in the first or eighth octile were classified as “poor” in the dimension of sleep timing. Men who responded that it took 30 minutes or more to fall asleep were classified as “poor” on the sleep onset latency dimension. Men who reported sleeping less than 7 hours or 9 hours or more were classified as “poor” in the sleep duration dimension. These items are very similar to but not exactly those of the original SATED scale. A multidimensional index of poor sleep health was calculated as the sum of the number of these

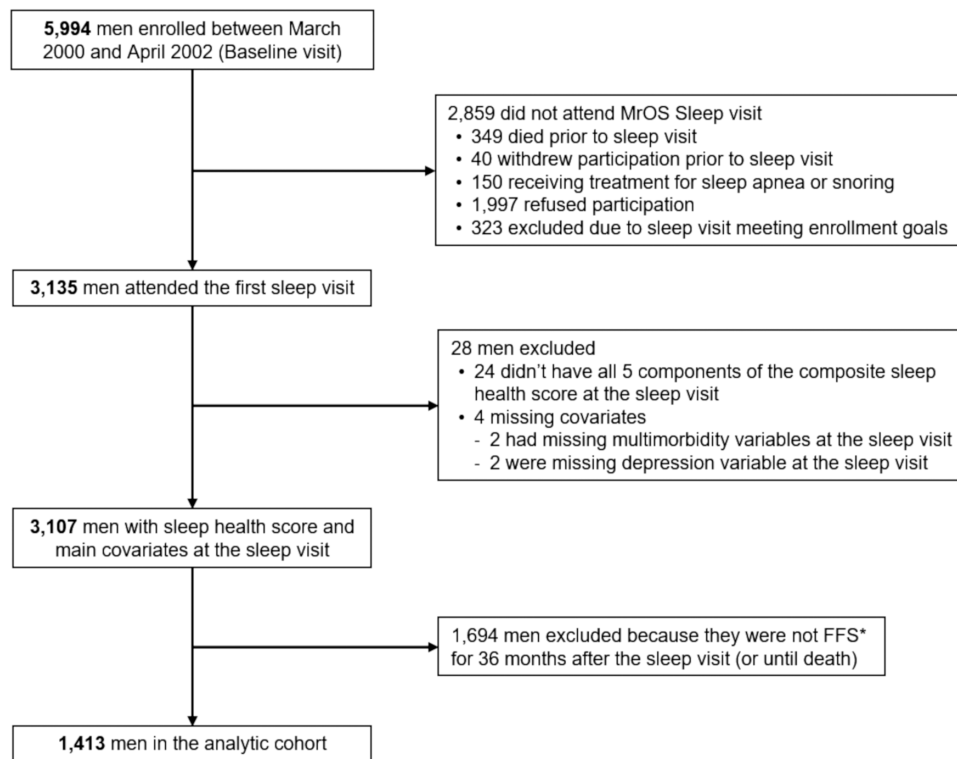


Figure 1. Participant flow. \*FFS, Fee-for-Service.

five dimensions self-reported as “poor,” and then categorized as 0, 1, 2, or  $\geq 3$  poor sleep dimensions. These ordinal categories were chosen to capture the variation of impaired sleep health dimensions yet having enough men (171) in the most impaired category of  $\geq 3$  so as to get stable estimates of the association of impaired self-reported poor sleep health dimensions with health care costs.

### Other covariates

At the first MrOS Sleep visit, men were asked about smoking status, self-reported health status, and their current caffeine intake. They were asked if they had ever been diagnosed by a physician with any of the following medical conditions: hypertension, congestive heart failure, coronary or myocardial infarction, angina, stroke, diabetes mellitus, chronic obstructive pulmonary disease (COPD), osteoarthritis, rheumatoid arthritis, Parkinson’s disease, osteoporosis, liver disease, chronic kidney disease/failure, intermittent claudication or pain in legs from blockage of arteries, transient ischemic attack, and cancer. A multimorbidity score was calculated as the number of the diagnosed conditions and categorized as 0, 1, 2, 3, or  $\geq 4$  (range 0–16). Functional limitations were assessed as the number (out of a total of five) of instrumental activities of daily living (IADLs) that men self-reported difficulty performing and were categorized as 0, 1, or  $\geq 2$  impaired IADLs. Depressive symptoms were measured with the 15-item Geriatric Depression Scale (GDS-15) and were categorized as none or minimal (GDS-15 score 0 or 1), mild (GDS-15 score 2–5), or moderate-severe (GDS-15 score  $\geq 6$ ) [43]. Global cognitive function was assessed

with the modified Mini-Mental State Exam (3MS) and scored from 0 to 100 [44]. Self-reported race and educational status were recorded at the main MrOS baseline visit. A comprehensive examination included measurements of body weight and height. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. Vital status was ascertained from the Medicare Beneficiary file.

### Health care utilization outcomes

Our primary outcome variable was total health care costs for the 36 months after the MrOS sleep visit (or until death for the 101 men [7.1%] who died before the 3-year anniversary of the sleep visit). We assessed health care costs over 3 years rather than 1 year to average out stochastic year-to-year variation in health care costs so that total health care cost estimations are more stable. Total health care costs were calculated as the sum of costs for hospital stays, skilled nursing facility (SNF) stays paid under Medicare part A, inpatient rehabilitation facility (IRF) stays, outpatient care, and home health care for that time period. By incorporating all these components of health care, total health care costs represent a measure of the overall health care burden. All hospital stays, Part A paid SNF stays, and IRF stays during that year were identified in the Medical Provider Analysis and Review (MedPAR) file. Standardized costs for hospital stays, SNF stays, and IRF stays were estimated using previously published and validated methods [45–47]. The costs of all units of utilization were adjusted for health care cost inflation to US 2018 dollars, using previously published methods [47].

## Statistical analyses

Generalized linear models (GLMs) were used to estimate the association of the poor sleep health dimensions with mean annualized total direct health care costs over the subsequent 36 months. Gamma distributions with log links were chosen based on Modified Park [48] and Pregibon link [49] tests. Thirty men (2.1%) had zero health care costs over the 3-year follow-up period, and we added \$1 to the cost of all 1,413 men so that all of them were included in our analytic models. The associations of self-reported poor sleep health dimensions compared with the reference group (no poor sleep health dimensions) were expressed as the cost ratio (CR) of the annualized cost for men with poor sleep health dimensions divided by the annualized cost of the reference group. Secondary analyses were done to estimate the association of poor self-reported sleep on each sleep dimension separately with total health care costs compared with no impairment on that specific sleep dimension.

Logistic models were used to estimate the associations of the multidimensional measure of poor sleep health with risks of at least one hospitalization and risk of at least one SNF stay. Men with no impairment in any sleep health dimension were the referent group.

Base models were adjusted for age, race, and study enrollment site. A second set of models added potentially important confounders (self-rated health, global cognitive function, and educational status). The third set of models additionally adjusted individually for multimorbidity, functional limitations (operationalized as the number of impaired IADLs), or depressive symptoms, as these characteristics may be confounding or mediating variables of the association of sleep health with health care costs. The final multivariable models adjusted simultaneously for all of these predictors.

Two sets of sensitivity analyses were performed. First, we estimated associations of self-reported poor sleep health dimensions with total health care costs excluding the 101 men (7.1%) who died during the 3-year follow-up period. Second, we estimated the age-, race-, and study site-adjusted associations of self-reported poor sleep health dimensions with total health care costs excluding men who on polysomnography had evidence of moderate to severe sleep apnea (Apnea-Hypopnea Index  $\geq 15$ ), who reported a diagnosis of sleep disorder other than sleep apnea, or who were taking benzodiazepines or nonbenzodiazepine, nonbarbiturate sedative hypnotics. All significance levels reported were two-sided and all analyses were conducted using SAS version 9.4 (SAS Institute Inc, Cary, NC).

## Results

Men at baseline with a higher number of poor sleep health dimensions were more likely to be nonwhite, to self-report impaired health status, and to have less education (Table 1). Those with a higher number of poor sleep health dimensions were more likely to report IADL impairment, more medical conditions, had a greater burden of depressive symptoms, and had slightly greater cognitive impairment (lower 3MS scores, Table 1).

### Associations of self-reported poor multidimensional sleep health with total health care costs

Median annualized total health care costs in the following 3-year period increased in a monotonic manner from \$3,616

(interquartile range [IQR] 1,523–7,875) among men with no impairment in sleep health dimensions to \$3,716 (IQR 1,642–9,093) among those with one impaired dimension, \$4,416 (IQR 1,854–11,343) among those with two impaired dimensions, and to \$5,819 (IQR 1,936–15,569) among men with three or more impaired dimensions. After adjustment for age, race, and study enrollment site, the annualized total health care costs were higher for men with two (CR 1.38, 95% confidence interval [CI] 1.15 to 1.65) and for men with three or more (CR 1.74, 95% CI 1.39 to 2.18) impaired sleep health dimensions compared with men with no impaired dimension (Table 2). These CRs were minimally attenuated and remained significant after multivariable adjustment, including accounting for differences in educational status, self-rated health, global cognitive function, multimorbidity, functional limitations, and depressive symptoms.

When examined separately, all sleep health dimensions except for poor sleep timing were associated with higher subsequent total health care costs even after full multivariable adjustment (Supplementary Table S2). Self-reported poor sleep satisfaction (CR 1.38, 95% CI 1.16 to 1.63) and excessive daytime sleepiness (CR 1.38, 95% CI 1.13 to 1.67) had the strongest associations, followed by short or long sleep duration (CR 1.19, 95% CI 1.04 to 1.37), and longer sleep latency (CR 1.19, 95% CI 1.02 to 1.39).

The age-, race-, and site-adjusted associations of self-reported poor sleep health dimensions with total health care costs remained highly significant when men with moderate to severe sleep apnea (Apnea-Hypopnea Index  $\geq 15$ ), a self-reported diagnosis of sleep disorder other than sleep apnea, or those who were taking benzodiazepines or nonbenzodiazepine, nonbarbiturate sedative hypnotics, or any one of these were excluded (Supplementary Table S3). Among the subset of 855 men who have none of the above stated exclusions, total health care costs among men with three or more poor sleep health dimensions were almost twofold higher (CR 1.90, 95% CI 1.40 to 2.57) compared with men with no poor sleep health dimensions.

Among the 1,312 men (92.9%) who survived the entire 3-year follow-up period, median annualized outpatient costs were \$3,445 (IQR 1,480–7,238) for men with no poor sleep health dimensions, \$3,455 (IQR 1,532–8,378) for men with one poor sleep health dimension, \$3,789 (1,673–9,268) for men with two poor sleep health dimensions, and \$4,693 (IQR 1,823–12,445) for men with three or more poor sleep health dimensions. Among survivors, men with three or more poor sleep health dimensions vs. those with no impaired dimensions had a modest increase in subsequent annualized total health care costs (CR 1.39, 95% CI 1.12 to 1.73; Table 3). However, this association was attenuated and no longer significant after multivariable adjustment (CR 1.22, 95% CI 0.98 to 1.53).

### Associations of self-reported poor sleep multidimensional sleep health with risk of hospitalization and SNF stay

Over the 3-year follow-up period, men with impairments in sleep health dimensions were more likely to be hospitalized. For example, 36.1% of men with no impairment in sleep health dimensions had one or more hospital stays vs. 46.2% of men with three or more impaired sleep health dimensions. Adjusted for age, race, and study enrollment site, men with two impairments in sleep health dimensions (odds ratio [OR] 1.37, 95% CI 1.02 to 1.86) and men with three or more impairments in sleep health



**Table 1.** Baseline characteristics of overall cohort and by index of poor multidimensional sleep health

Characteristics	Overall cohort (n = 1,413)	Poor Sleep Health Index				P-value
		0 (n = 452)	1 (n = 473)	2 (n = 317)	≥3 (n = 171)	
Age, years, mean (SD)	76.5 (5.7)	76.2 (5.7)	76.6 (5.7)	76.9 (5.6)	76.6 (6.1)	0.41
Race, n (%)						0.02
White	1288 (91.2)	426 (94.2)	430 (90.9)	279 (88.0)	153 (89.5)	
Other	125 (8.8)	26 (5.8)	43 (9.1)	38 (12.0)	18 (10.5)	
Fair, poor or very poor health status, n (%)	174 (12.3)	37 (8.2)	49 (10.4)	48 (15.1)	40 (23.4)	<0.001
Ever smoker, n (%)	827 (58.5)	255 (56.4)	273 (57.7)	188 (59.3)	111 (64.9)	0.27
Caffeine intake, mg/day, mean (SD)	231.7 (240.6)	238.5 (237.1)	233.5 (234.8)	216.2 (232.1)	237.4 (279.0)	0.62
Years of education, n (%)						<0.001
High school or less	244 (17.3)	56 (12.4)	80 (16.9)	66 (20.8)	42 (24.6)	
College/grad school	1169 (82.7)	396 (87.6)	393 (83.1)	251 (79.2)	129 (75.4)	
# IADL impairment (0–5), mean (SD)	0.3 (0.8)	0.2 (0.5)	0.3 (0.7)	0.5 (0.9)	0.7 (1.3)	<0.001
# IADL impairment (0–5), n (%)						<0.001
0	1121 (79.3)	379 (83.8)	397 (83.9)	231 (72.9)	114 (66.7)	
1	178 (12.6)	59 (13.1)	46 (9.7)	46 (14.5)	27 (15.8)	
≥2	114 (8.1)	14 (3.1)	30 (6.3)	40 (12.6)	30 (17.5)	
Geriatric Depression Scale score (0–15), n (%)						<0.001
0–1	847 (59.9)	331 (73.2)	294 (62.2)	154 (48.6)	68 (39.8)	
2–5	487 (34.5)	116 (25.7)	163 (34.5)	132 (41.6)	76 (44.4)	
≥6	79 (5.6)	5 (1.1)	16 (3.4)	31 (9.8)	27 (15.8)	
Medical conditions* (0–16), n (%)						0.004
0	211 (14.9)	77 (17.0)	70 (14.8)	45 (14.2)	19 (11.1)	
1	385 (27.2)	140 (31.0)	127 (26.8)	78 (24.6)	40 (23.4)	
2	363 (25.7)	125 (27.7)	126 (26.6)	69 (21.8)	43 (25.1)	
3	251 (17.8)	64 (14.2)	82 (17.3)	71 (22.4)	34 (19.9)	
≥4	203 (14.4)	46 (10.2)	68 (14.4)	54 (17.0)	35 (20.5)	
Body mass index, kg/m <sup>2</sup> , mean (SD)	27.1 (3.8)	27.0 (3.4)	27.0 (3.9)	27.3 (4.0)	27.5 (4.0)	0.37
3MS (range 0–100), mean (SD)	92.8 (6.2)	93.6 (5.5)	93.1 (5.9)	91.9 (7.1)	91.7 (6.6)	<0.001
Died during follow-up, n (%)	101 (7.1)	23 (5.1)	30 (6.3)	31 (9.8)	17 (9.9)	0.03

IADL, Instrumental Activities of Daily Living; 3MS, Mini Mental State Examination.

\*Medical conditions include hypertension, congestive heart failure, coronary or myocardial infarction, angina, stroke, diabetes mellitus, chronic obstructive pulmonary disease, osteoarthritis, rheumatoid arthritis, Parkinson's disease, osteoporosis, liver disease, chronic kidney disease/failure, intermittent claudication or pain in legs from blockage of arteries, transient ischemic attack, and cancer.

dimensions (OR 1.44, 95% CI 1.00 to 2.09) were more likely to be hospitalized compared with men with no impaired sleep health dimensions (Table 4). These associations were attenuated and no longer significant after full multivariable adjustment. Amongst the 1,312 men who survived the entire 3-year follow-up period, there was no evidence of an association of impairments in sleep health dimensions with odds of subsequent hospitalization.

Over the 3-year follow-up period, 5.1% of men with no impaired sleep health dimensions, 6.3% of men with one impaired dimension, 6.0% of men with two impaired dimensions, and 9.4% of men with three or more impaired dimensions had one or more SNF stays. Adjusted for age, race, and study enrollment site, there was no significant association between impaired sleep health dimensions and subsequent SNF stay (Table 5). This relationship was further attenuated after full multivariable adjustment. Among the 1,312 men who survived the entire 3-year follow-up period, there was no association between poor sleep health dimensions and subsequent SNF stay.

## Discussion

In this cohort of older community-dwelling men, impairment in multiple self-reported sleep health dimensions was associated with higher subsequent total health care costs, even after

consideration of multiple potential confounding and mediating factors, including burden of comorbid medical conditions, functional limitations, depressive symptoms, and cognitive impairment. Moreover, the association of impaired sleep health dimensions with total health care costs was not explained by a higher prevalence of objectively measured sleep apnea, other sleep disorder diagnoses, or use of sleep medications among those with poor sleep health. However, after excluding men who died during the 3-year follow-up period, the associations of poor sleep on these five dimensions were substantially attenuated and not significant after multivariable adjustment. Health care costs are higher during the final 6 months of life, regardless of the ultimate cause of death [32, 33]. Thus, it is possible that impaired sleep on these five dimensions in older men is a marker for limited life expectancy with its attendant high health care costs close to death, rather than being a true cause of increased health care costs. However, further research would be needed to examine if, among those men who are within a few years of death, the association of poor sleep health dimensions with health care costs is causal or attributable to other confounding variables associated with mortality.

These results are broadly consistent with many other studies of self-reported sleep impairment and health care utilization in younger populations. Using a cross-sectional analysis of

**Table 2.** Association of poor multidimensional sleep health with total health care costs

Characteristic	Cost ratio (95% confidence interval)					
	Base model*	P-value	Model 2†	P-value	Model 3‡	P-value
<b>Poor Sleep Health Index</b>						
0	Reference	<0.001	Reference	<0.001	Reference	<0.001
1	0.97 (0.82–1.13)		0.96 (0.82–1.12)		1.02 (0.88–1.20)	
2	1.38 (1.15–1.65)		1.32 (1.10–1.58)		1.24 (1.03–1.48)	
≥3	1.74 (1.39–2.18)		1.68 (1.34–2.11)		1.78 (1.42–2.23)	
Age	1.04 (1.03–1.06)	<0.001	1.04 (1.03–1.05)	<0.001	1.03 (1.02–1.04)	<0.001
<b>Race</b>						
White	Reference	0.004	Reference	<0.001	Reference	0.001
Other	0.70 (0.55–0.88)		0.65 (0.51–0.83)		0.67 (0.53–0.84)	
<b>Education</b>						
High school or less	—	—	0.93 (0.77–1.13)	0.48	0.94 (0.78–1.14)	0.54
College/grad school	—	—	Reference	—	Reference	—
<b>Self-reported health status</b>						
Poor, very poor, fair	—	—	1.36 (1.12–1.66)	0.002	1.06 (0.86–1.30)	0.58
Good, excellent	—	—	Reference	—	Reference	—
3MS (per 1 unit decrease)	—	—	0.99 (0.98–1.00)	0.07	0.99 (0.98–1.00)	0.01
<b>Medical conditions (0–15)**</b>						
0	—	—	—	—	Reference	<0.001
1	—	—	—	—	1.42 (1.16–1.75)	
2	—	—	—	—	1.43 (1.16–1.76)	
3	—	—	—	—	2.24 (1.79–2.81)	
≥4	—	—	—	—	3.16 (2.48–4.02)	
<b># of IADL impairments (0–5)</b>						
0	—	—	—	—	Reference	0.03
1	—	—	—	—	1.30 (1.07–1.59)	
≥2	—	—	—	—	1.05 (0.83–1.34)	
<b>GDS score (0–15)</b>						
0–1	—	—	—	—	Reference	0.28
2–5	—	—	—	—	1.04 (0.90–1.20)	
≥6	—	—	—	—	0.81 (0.60–1.10)	

3MS, Mini Mental State Examination; IADL, instrumental activities of daily living; GDS, Geriatric Depression Scale.

\*Adjusted for age, race, and study enrollment site.

†Model 2 adjusted for age, race, study enrollment site, self-reported health status, education, and 3MS score.

‡Model 3 adjusted for age, race, study enrollment site, self-reported health status, education, 3MS score, comorbid medical conditions, IADL impairments, and GDS score.

\*\*Medical conditions include hypertension, congestive heart failure, coronary or myocardial infarction, angina, stroke, diabetes mellitus, chronic obstructive pulmonary disease, osteoarthritis, rheumatoid arthritis, Parkinson's disease, osteoporosis, liver disease, chronic kidney disease/failure, intermittent claudication or pain in legs from blockage of arteries, transient ischemic attack, and cancer.

a cohort of Kansas state employees (mean age 45 years), Hui *et al.* [50] reported that those who self-reported (in response to a single question) that they sometimes, often, or always had trouble sleeping had higher total health care costs (ascertained directly with health care claims). Using a cross-sectional survey of 11,000 health plan insureds (mean age 52 years), Sarsour *et al.* [25] noted that self-reported moderate to severe insomnia on the Insomnia Severity Index was associated with higher total health care costs (ascertained with health care claims) over the prior 12 months, even after adjustment for Chronic Disease Score (a comorbidity measure based on chronic medication use) and mental health diagnoses. However, this study may have been compromised by nonresponse bias, as 78% of the eligible population did not participate in the survey. Two other studies

reported that self-reported insomnia (difficulty initiating or staying asleep, or waking feeling poorly rested) was associated with self-reported hospital [29, 51] and SNF stays [51] even after adjustment for comorbid medical conditions. In this cohort of community-dwelling older men, we previously reported that men with moderate to severe sleep apnea identified on overnight polysomnography had an increased risk of subsequent hospitalization (but not higher subsequent total health care costs) not entirely explained by comorbid conditions [52]. Other studies have reported that patients who have been given an ICD-9 diagnosis of insomnia [28, 53] or obstructive sleep apnea [3, 31] have higher total health care costs [28, 31, 53] and/or hospital stays and emergency department visits [3] after accounting for comorbid medical conditions. However, given the younger

**Table 3.** Association of poor multidimensional sleep health with total health care costs among survivors

Characteristic	CR (95% CI)					
	Base model*	P-value	Model 2†	P-value	Model 3‡	P-value
<b>Poor Sleep Health Index</b>						
0	Reference	0.01	Reference	0.03	Reference	0.32
1	1.01 (0.87–1.18)		1.01 (0.86–1.18)		1.03 (0.88–1.19)	
2	1.16 (0.97–1.38)		1.14 (0.95–1.36)		1.05 (0.88–1.26)	
≥3	1.39 (1.12–1.73)		1.34 (1.07–1.67)		1.22 (0.98–1.53)	
Age	1.02 (1.00–1.03)	0.03	1.02 (1.01–1.04)	<0.001	1.02 (1.01–1.03)	0.003
<b>Race</b>						
White	Reference	0.02	Reference	0.01	Reference	0.06
Other	0.76 (0.60–0.95)		0.74 (0.58–0.93)		0.80 (0.63–1.01)	
<b>Education</b>						
High school or less	—	—	0.96 (0.80–1.15)	0.65	0.92 (0.77–1.10)	0.37
College/grad school	—	—	Reference		Reference	
<b>Self-reported health status</b>						
Poor, very poor, fair	—	—	1.38 (1.14–1.68)	<0.001	1.12 (0.92–1.37)	0.24
Good, excellent	—	—	Reference		Reference	
3MS (per 1 unit decrease)	—	—	1.00 (0.98–1.01)	0.42	1.00 (0.99–1.01)	0.97
<b>Medical conditions (0–15)**</b>						
0	—	—	—	—	Reference	<0.001
1	—	—	—	—	1.36 (1.12–1.65)	
2	—	—	—	—	1.65 (1.35–2.01)	
3	—	—	—	—	2.34 (1.88–2.91)	
≥4	—	—	—	—	2.69 (2.13–3.41)	
<b># of IADL impairments (0–5)</b>						
0	—	—	—	—	Reference	0.006
1	—	—	—	—	1.32 (1.08–1.60)	
≥2	—	—	—	—	1.28 (1.00–1.64)	
<b>GDS score (0–15)</b>						
0–1	—	—	—	—	Reference	0.05
2–5	—	—	—	—	1.14 (1.00–1.31)	
≥6	—	—	—	—	0.85 (0.63–1.15)	

3MS, Mini Mental State Examination; IADL, instrumental activities of daily living; GDS, Geriatric Depression Scale.

\*Adjusted for age, race, and study enrollment site.

†Model 2 adjusted for age, race, study enrollment site, self-reported health status, education, and 3MS score.

‡Model 3 adjusted for age, race, study enrollment site, self-reported health status, education, 3MS score, comorbid medical conditions, IADL impairments, and GDS score.

\*\*Medical conditions include hypertension, congestive heart failure, coronary or myocardial infarction, angina, stroke, diabetes mellitus, chronic obstructive pulmonary disease, osteoarthritis, rheumatoid arthritis, Parkinson's disease, osteoporosis, liver disease, chronic kidney disease/failure, intermittent claudication or pain in legs from blockage of arteries, transient ischemic attack, and cancer.

ages of participants in these studies, the effect of short-term mortality risk on the association of specific sleep disorders or complaints with health care utilization was not addressed in any of these investigations.

There is a paucity of studies that have examined the association of impaired multidimensional sleep health with health care costs and utilization. In addition to our study of older men, this association was examined in a cohort of women in late life enrolled in the SOF [54]. Adjusted for age, race, and study site, the strength of association appeared to be weaker in magnitude than what we found in these older men. In addition, among the cohort of older women, the association was explained in large part by the higher prevalence of multimorbidity, functional limitations, and depressive symptoms among women with impaired sleep health. Excluding women who died during the follow-up period did not alter the findings. Our cohort of MrOS men was somewhat younger (mean age 76 years) than our cohort of SOF women (mean age 84 years) and had lower prevalence of comorbid medical conditions, functional limitations,

and depressive symptoms. Whether there are sex differences in the relationship between impaired sleep health and health care costs or whether differences in characteristics between the two populations that account for the stronger associations of impaired sleep health with health care costs we observed in older men vs. women is uncertain.

The mechanism(s) underlying the complex association of poor multidimensional sleep health with health care costs in older adults is unclear. The impaired physiological and mental reserve associated with poor sleep may reduce the capacity for self-care, leading to greater likelihood to seek medical attention for subacute and chronic conditions. However, this impaired reserve may meaningfully influence health care utilization independent of comorbid medical conditions and functional limitations only when it is severe enough to also contribute to mortality risk. Confirmation of these hypotheses would be consistent with our finding that the association of multidimensional poor sleep is much weaker in those men who survive at least 3 years beyond their sleep assessment.



**Table 4.** Association of poor multidimensional sleep health with risk of hospitalization

Characteristic	Odds ratio (95% CI)			
	Full sample (n = 1,413)		Survivors through 3-year follow-up (n = 1,312)	
	Base model*	Full multivariable model†	Base model*	Full multivariable model†
<b>Poor Sleep Health Index</b>				
0	Reference	Reference	Reference	Reference
1	1.00 (0.76–1.31)	0.94 (0.71–1.25)	0.99 (0.74–1.31)	0.92 (0.69–1.24)
2	1.37 (1.02–1.86)	1.19 (0.87–1.64)	1.29 (0.94–1.78)	1.13 (0.81–1.58)
≥3	1.44 (1.00–2.09)	1.19 (0.80–1.75)	1.30 (0.88–1.92)	1.06 (0.70–1.60)
Age	1.06 (1.04–1.08)	1.04 (1.02–1.07)	1.05 (1.02–1.07)	1.03 (1.01–1.06)
<b>Race</b>				
White	Reference	Reference	Reference	Reference
Other	0.73 (0.48–1.11)	0.70 (0.45–1.08)	0.71 (0.46–1.11)	0.73 (0.46–1.17)
<b>Education</b>				
High school or less	—	0.95 (0.69–1.31)	—	1.02 (0.73–1.43)
College/grad school	—	Reference	—	Reference
<b>Self-reported health status</b>				
Poor, very poor, fair	—	0.86 (0.60–1.23)	—	0.84 (0.57–1.23)
Good, excellent	—	Reference	—	Reference
3MS Score (per 1 unit decrease)	—	0.99 (0.97–1.01)	—	1.00 (0.98–1.03)
<b>Medical conditions (0–15)‡</b>				
0	—	Reference	—	Reference
1	—	1.68 (1.15–2.47)	—	1.83 (1.22–2.76)
2	—	1.63 (1.10–2.41)	—	1.86 (1.23–2.82)
3	—	2.39 (1.58–3.61)	—	2.57 (1.65–3.99)
≥4	—	3.02 (1.95–4.69)	—	3.18 (1.98–5.08)
<b>IADL impairments (0–5)</b>				
0	—	Reference	—	Reference
1	—	1.50 (1.07–2.12)	—	1.40 (0.97–2.01)
≥2	—	1.46 (0.94–2.27)	—	1.51 (0.95–2.41)
<b>GDS score (0–15)</b>				
0–1	—	Reference	—	Reference
2–5	—	1.26 (0.98–1.62)	—	1.28 (0.99–1.67)
≥6	—	1.13 (0.67–1.92)	—	1.16 (0.66–2.06)

3MS, Mini Mental State Examination; IADL, instrumental activities of daily living; GDS, Geriatric Depression Scale.

\*Adjusted for age, race, and study enrollment site.

†Full multivariable model adjusted for age, race, study enrollment site, self-reported health status, education, 3MS score, comorbid medical conditions, IADL impairments, and GDS score.

‡Medical conditions include hypertension, congestive heart failure, coronary or myocardial infarction, angina, stroke, diabetes mellitus, chronic obstructive pulmonary disease, osteoarthritis, rheumatoid arthritis, Parkinson's disease, osteoporosis, liver disease, chronic kidney disease/failure, intermittent claudication or pain in legs from blockage of arteries, transient ischemic attack, and cancer.

Our study has numerous strengths. Our investigation is the first study to investigate the association of poor sleep on multiple dimensions defined by a self-report scale very similar to the SATED scale with health care costs and utilization in older men. Men enrolled in MrOS are broadly representative of community-dwelling older men in the United States, were not selected because of sleep problems, and are comprehensively characterized. We relied on direct health care Medicare claims to ascertain health care utilization and costs, rather than self-report. Our study design was longitudinal rather than cross sectional; we estimated the association of baseline impaired sleep with subsequent health care costs and utilization.

Our study does have some limitations. Our characterization of poor sleep health dimensions is similar to but not the same as the original SATED scale. Further research is needed on how to best define these sleep health dimensions, the best thresholds at which to consider a particular dimension “poor,” and how those sleep health definitions and thresholds are associated

with different health outcomes. Our results may not be generalizable to younger and nonwhite populations, since only 9% of the cohort is nonwhite. We excluded older men who were not enrolled in Medicare FFS, although characteristics of MrOS men enrolled in Medicare FFS are very similar to those enrolled in Medicare Advantage.

In conclusion, poor self-reported sleep on multiple dimensions is associated with higher total health care costs in older men, independent of comorbid chronic medical illnesses, functional limitations, depressive symptoms, and other potential confounders. This may be due to higher mortality and increased health care costs toward the end of life among those with poor sleep health. Further research is needed to determine if the association is causal or attributable to confounding variables that also predict mortality.

## Supplementary Material

Supplementary material is available at *SLEEP* online.

**Table 5.** Association of poor multidimensional sleep health with risk of SNF stay

Characteristic	Odds ratio (95% CI)			
	Full Sample (n = 1,413)		Survivors through 3-year follow-up (n = 1,312)	
	Base model*	Full multivariable model†	Base model*	Full multivariable model†
Poor Sleep Health Index				
0	Reference	Reference	Reference	Reference
1	1.22 (0.69–2.17)	1.14 (0.64–2.05)	1.42 (0.71–2.85)	1.34 (0.65–2.75)
2	1.17 (0.62–2.21)	0.88 (0.45–1.73)	1.41 (0.64–3.08)	1.15 (0.50–2.63)
≥3	1.86 (0.93–3.71)	1.19 (0.55–2.57)	2.03 (0.86–4.78)	1.36 (0.53–3.50)
Age	1.13 (1.08–1.17)	1.10 (1.05–1.15)	1.10 (1.05–1.16)	1.08 (1.03–1.14)
Race				
White	Reference	Reference	Reference	Reference
Other	1.05 (0.43–2.52)	0.91 (0.36–2.30)	0.96 (0.33–2.79)	0.94 (0.31–2.89)
Education				
High School or less	—	0.80 (0.42–1.52)	—	0.86 (0.39–1.88)
College/grad school	—	Reference	—	Reference
Self-reported health status				
Poor, very poor, fair	—	1.33 (0.70–2.52)	—	1.22 (0.56–2.66)
Good, excellent	—	Reference	—	Reference
3MS Score (per 1 unit decrease)	—	0.98 (0.95–1.01)	—	1.00 (0.95–1.05)
Medical conditions (0–15)‡				
0	—	Reference	—	Reference
1	—	0.99 (0.42–2.35)	—	1.23 (0.37–4.11)
2	—	0.85 (0.35–2.06)	—	1.70 (0.53–5.43)
3	—	1.85 (0.79–4.34)	—	3.03 (0.96–9.58)
≥4	—	2.38 (1.02–5.58)	—	3.38 (1.05–10.90)
IADL impairments (0–5)				
0	—	Reference	—	Reference
1	—	2.26 (1.25–4.11)	—	2.69 (1.33–5.46)
≥2	—	2.38 (1.19–4.76)	—	2.58 (1.12–5.98)
GDS score (0–15)				
0–1	—	Reference	—	Reference
2–5	—	0.90 (0.53–1.53)	—	0.91 (0.48–1.71)
≥6	—	1.02 (0.41–2.51)	—	0.75 (0.24–2.41)

SNF, skilled nursing facility; 3MS, Mini Mental State Examination; IADL, instrumental activities of daily living; GDS, Geriatric Depression Scale.

\*Adjusted for age, race, and study enrollment site.

†Full multivariable model adjusted for age, race, study enrollment site, self-reported health status, education, 3MS score, comorbid medical conditions, IADL impairments, and GDS score.

‡Medical conditions include hypertension, congestive heart failure, coronary or myocardial infarction, angina, stroke, diabetes mellitus, chronic obstructive pulmonary disease, osteoarthritis, rheumatoid arthritis, Parkinson's disease, osteoporosis, liver disease, chronic kidney disease/failure, intermittent claudication or pain in legs from blockage of arteries, transient ischemic attack, and cancer.

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