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Objectively Measured Sleep Quality and Nursing Home Placement in Older Women

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Conflict of Interest

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Author Contributions:
Dr. Adam Spira: developed study concept and design, analyzed and interpreted data, prepared manuscript.
Dr. Kenneth Covinsky: developed study concept and design, and participated in data analysis and interpretation, and in manuscript preparation.
Dr. George Rebok: participated in data analysis and interpretation, and in manuscript preparation.
Dr. Susan Redline: participated in the study design, data interpretation, and review and preparation of the manuscript.
Dr. Katie Stone: developed study concept and design, obtained funding, participated in data analysis and interpretation of data and manuscript preparation.
Dr. Kristine Yaffe: developed study concept and design, participated in data analysis and interpretation, and in manuscript preparation.

Abstract

OBJECTIVES—To determine the association between objectively measured sleep and subsequent placement in a nursing home or a personal care home.

DESIGN—Prospective cohort

SETTING—Homes of participants in an ongoing study

PARTICIPANTS—1,664 community-dwelling women, mean age 83 ±4 years

MEASUREMENTS—At baseline, participants completed an average of 4 nights of wrist actigraphy; they provided data on place of residence at baseline and at follow-up, 5 years later.

RESULTS—At baseline, participants had a mean total sleep time of 408 ±72 minutes, mean wake after sleep onset of 71±43 minutes, and mean sleep efficiency of 79 ±11 percent. At follow-up, 71 (4%) were residing in a nursing home and 127 (8%) were in a personal care home. Compared to women with the least wake after sleep onset (by quartile), those with the most had more than twice the odds of placement in a nursing home (adjusted odds ratio (AOR) = 2.94, 95% confidence interval (CI) 1.34, 6.44) or a personal care home (AOR = 2.33, 95% CI 1.26, 4.30). Similarly, compared to women with the highest sleep efficiency, those with the lowest had more than three times the odds of nursing home placement (AOR = 3.25, 95% CI 1.35, 7.82) and more than twice the odds of placement in a personal care home (AOR = 2.38, 95% CI 1.33, 4.24). There was no association between sleep duration and placement.

CONCLUSION—Among very old community-dwelling women, greater wake after sleep onset and lower sleep efficiency are risk factors for placement in a nursing home or personal care home. Sleep duration alone does not appear to increase the risk of placement in these long-term care settings.

Keywords

sleep; actigraphy; nursing home; placement; women

INTRODUCTION

Sleep disturbances, including altered sleep duration and increased sleep fragmentation, are common among older adults. Over 40% of adults aged 65 and older report difficulty falling or staying asleep.[1] Sleep complaints have been linked to disability in older adults, including impairment in activities of daily living or related tasks[1] and in mobility.[2] In addition, when sleep has been objectively estimated using actigraphy—a method of quantifying sleep by recording movement at the wrist—results have indicated that abnormal sleep duration and sleep fragmentation are associated with impairment in instrumental activities of daily living and lower performance on objective measures of physical function, including gait speed.[3]

Despite the growing literature on sleep disturbance and disability, relatively little is known about the association between sleep disturbance in older adults and risk of placement in long-term care facilities. Studies of retrospective reports of caregivers of institutionalized older adults suggest that problems with care recipients' nocturnal behavior, including sleep disturbance, are poorly tolerated by caregivers,[4] and are among the most common reasons they identify for institutionalization.[5] Prospective studies of the association between sleep disturbance and nursing home placement, however, have focused on the general population of older adults or on elders with AD, and have yielded conflicting results.[1, 6, 7] A limitation shared by these studies of sleep and institutionalization is their reliance on subjective (i.e., self- or informant-report) measures of sleep. This is critical, because the results of subjective

sleep measures may be subject to a range of biases and often do not agree with estimates made from objective measures such as actigraphy.[8]

In the present prospective study, we used wrist actigraphy to determine whether sleep duration and fragmentation in very old community-dwelling women predict nursing home placement over a five-year period. Given the relative lack of data concerning sleep disturbance as a predictor of placement in other long-term care settings, we also determined the association between these sleep parameters and placement in a personal care home (i.e., assisted living facility, adult foster home).

METHODS

Participants

Participants were women in the Study of Osteoporotic Fractures (SOF), a prospective cohort study of aging. SOF enrolled 9,704 mostly white women between 1986 and 1988 from Baltimore, MD; Minneapolis, MN; Monongahela Valley (Pittsburgh), PA; and Portland, OR, using population-based listings. Participants have been followed approximately every 2.5 years since enrollment, and 662 black women were recruited between 1997 and 1998. Institutional review boards at each SOF site approved the research, and participants provided informed consent.

The present study used data from the Year-16 (2002–2004) visit (referred to here as "baseline"), and from the Year-20 (2006–2008) visit (referred to as "follow-up"). Of the 4,727 women who participated in the Year-16 visit, we excluded 1,009 women from the Baltimore SOF site, which was not included in the follow-up visit. Of the 3,718 women who remained, 2,570 had actigraphy data for at least one of the three sleep parameters we studied (see below). We excluded 147 women identified at baseline as residing in a "nursing home" ($n = 21$), "personal care home (adult foster home, assisted living)" ($n = 60$), or—due to its ambiguous meaning—"other" residence ($n = 66$). In addition, we excluded four women who were missing data on place of residence at baseline. Of the remaining 2,419, there were 1,688 with data on place of residence at the follow-up visit. We excluded 24 of these 1,688 women with data indicating "other" residence at follow-up, leaving a sample of 1,664 women. Of the 731 women missing residence data at follow-up, 583 were confirmed to have died between baseline and follow-up (based on death certificate), 4 died according to proxy report but this had not been confirmed, 79 terminated participation, and 65 were unaccounted for.

Actigraphy

At the baseline visit, participants were asked to complete at least three consecutive 24-hour periods of actigraphy, wearing SleepWatch-O actigraphs (Ambulatory Monitoring, Inc., Ardsley, NY) on their non-dominant wrists. We used Action W-2 software (Ambulatory Monitoring, Inc.) to edit and score actigraphy data in proportional integration mode (PIM) using the University of California, San Diego (UCSD) algorithm.[9] To assist with editing of actigraphy data (e.g., to identify when participants were in bed with the intention of sleeping), participants completed sleep diaries in which they recorded a range of data, including times they got into and out of bed or removed the actigraph. We derived standard indices of sleep duration and fragmentation: total sleep time (TST; total minutes slept while in bed); wake after sleep onset (WASO; total minutes spent awake after first 20-minute sleep bout); and sleep efficiency (SE; (total minutes slept/total time in bed) × 100). All sleep parameters were averaged across nights of actigraphy.

Place of Residence

At baseline and follow-up, participants or informants reported whether participants lived in a "private home or apartment," "retirement home or senior complex," "nursing home," "personal care home (adult foster home, assisted living)," or "other" residence.

Other Measures

Participants provided demographic data upon enrollment in SOF. At the Year-16 visit, they completed questionnaires in which they indicated whether or not they lived alone; those reporting that they lived with others were asked whether or not they lived with a spouse. Participants also indicated whether or not a healthcare provider had ever told them they have any medical problems from a list of comorbidities (e.g., hypertension, diabetes, coronary artery disease, congestive heart failure). They also reported whether or not they had difficulty, and the degree of difficulty they had, with instrumental activities of daily living (IADLs; i.e., preparing meals, doing heavy housework, shopping) and mobility (i.e., walking 2 to 3 blocks, climbing 10 steps, descending 10 steps). They were weighed and measured, and body mass index was calculated (BMI; kg/m^2). In addition, they were asked to bring medications and supplements taken over the prior 30 days to the Year-16 visit; a computerized dictionary was used to code medications according to brand or generic name.[10] Participants' general cognitive status was assessed by the Mini-Mental State Examination (MMSE).[11] Depressive symptoms were assessed with the 15-item Geriatric Depression Scale[12] (GDS), and anxiety symptoms were assessed using the Goldberg Anxiety Scale.[13]

Statistical Analyses

To determine the association between sleep parameters at baseline and risk of placement in a nursing home or personal care home at follow-up, we conducted unadjusted and multivariable-adjusted logistic regression analyses. Each model included quartiles of an actigraphic sleep parameter—measured at our study baseline—as the primary predictor. For each of the three sleep indices—TST, WASO, SE—the reference quartiles contained the women with the longest TST, the least WASO, and the highest SE, respectively. We studied two separate outcomes: (1) new residence in a nursing home at follow-up; and (2) new residence in a personal care home at follow-up. The reference category for each outcome was "community dwelling" status at follow-up, which we defined as responses indicating residence in a "private home or apartment," or "retirement home or senior complex." After fitting each regression model, we performed tests for linear trend across sleep parameter quartiles.

Potential confounders were included in multivariable-adjusted models based on their association with any actigraphic sleep parameter and either outcome at the $p \leq 0.10$ level according to Kruskal-Wallis tests for continuous variables, χ^2 or Fisher's exact tests for categorical variables, or ordinal logistic regression (with covariates as predictors and sleep parameter quartiles as outcomes). Based on these criteria, multivariable models were adjusted for age, race (white or non-white), BMI, MMSE score, number of IADL or mobility impairments, GDS score, Alzheimer's disease, congestive heart failure, osteoarthritis, antidepressant use, and benzodiazepine use. Six participants without complete data for all GDS items were excluded from multivariable models.

We explored whether a U-shaped association existed between TST and outcomes by fitting models (unadjusted and unadjusted, as described above) with TST as a continuous predictor and using likelihood ratio χ^2 tests to compare them to models that also included TST as a quadratic term (TST^2). Results were non-significant, indicating that inclusion of a quadratic term failed to improve model fit, and that a U-shaped association was unlikely.

We used an α <0.05 for statistical significance. Analyses were conducted with Stata/MP 12.1 (StataCorp, College Station, TX).

RESULTS

On average, women were 83.0 ±3.5 (mean ± standard deviation) years of age at baseline and 87.9 ±3.5 at follow-up. Of the 1,664 women, 179 (10.8%) were non-white and 624 (37.5%) had more than a high-school education. A total of 987 women (59.3%) lived alone at baseline; of the 677 women who lived with others, 463 (68.4%) lived with a spouse.

Participants wore actigraphs for an average of 4.1 ±0.7 nights (range 1 – 8). They had a mean TST of 408.4 ±72.1 minutes, mean WASO of 71.3 ±43.0 minutes, and mean SE of 78.6 ±10.9 percent (Table 1). Across SE quartiles, participants differed by race, number of IADL/mobility impairments, BMI, MMSE score, depressive symptoms, anxiety symptoms, antidepressant use, and several medical conditions (Table 2).

The average interval between baseline and follow-up was 5.0 ±0.6 years. At follow-up, of the 1,664 women who were community-dwelling at baseline, 71 (4.3%) were living in a nursing home and 127 (7.6%) were in a personal care home. Overall, 1,466 (88.1%) of the 1,664 women remained community dwelling at follow-up.

Nursing Home Placement

In unadjusted analyses, women in the quartile with the most WASO had almost three times the odds of nursing home placement at follow-up, compared to women with the least WASO (odds ratio (OR) = 2.80, 95% confidence interval (CI) 1.41, 5.55) (Table 3). This association remained after adjustment for potential confounders (OR = 2.94, 95% CI 1.34, 6.44). In addition, across quartiles of WASO, there was a linear trend, such that greater WASO was associated with a greater odds of nursing home placement, in both unadjusted and multivariable-adjusted models (p for trend <0.001 and p for trend = 0.004, respectively).

We observed similar associations between lower SE and nursing home placement. In unadjusted analyses, the quartile of women with the second-lowest SE had over 2.5 times the odds of placement (OR = 2.59, 95% CI 1.18, 5.71), and those with the lowest SE had over 3 times the odds of placement (OR = 3.31, 95% CI 1.54, 7.14), compared to those with the highest SE. These associations remained significant after multivariable adjustment (OR = 2.47, 95% CI 1.01, 6.07 and OR = 3.25, 95% CI 1.35, 7.82, respectively). In the unadjusted model, there was a linear association across quartiles of SE, such that lower SE was associated with an increased risk of nursing home placement (p for trend <0.001), and this linear trend remained in the multivariable-adjusted model (p = 0.004).

There was no association between TST and nursing home placement.

Placement in a Personal Care Home

In unadjusted analyses, women in the quartile with the second-highest amount of WASO had almost twice the odds of placement in a personal care home compared to women in the quartile with the least WASO (OR = 1.92, 95% CI 1.09, 3.38); women in the quartile with the most WASO had an even greater odds of placement (OR = 2.24, 95% CI 1.28, 3.90) (Table 4). These associations increased after adjustment for potential confounders. There was a linear trend across quartiles of WASO; greater WASO was associated with a greater odds of placement in a personal care home in unadjusted (p for trend = 0.003) and adjusted models (p for trend = 0.005).

In unadjusted analyses, women in the quartile with the lowest SE had almost twice the odds of placement in a personal care home, compared to those with the highest SE (OR = 1.93, 95% CI 1.15, 3.26). This association increased after adjustment (OR = 2.38, 95% CI 1.33, 4.24). In addition, there was a linear trend across SE quartiles; lower SE was associated with a greater odds of placement in a personal care home in both unadjusted and multivariable-adjusted models (p for trend = 0.010 and p for trend = 0.003, respectively).

There was no association between TST and personal care home placement.

DISCUSSION

In this study of community-dwelling older women, we found that greater wake after sleep onset and lower sleep efficiency, objectively measured using actigraphy, each were associated with substantial increases in the odds of placement in a nursing home or a personal care home. In contrast with these indices of sleep fragmentation, sleep duration was not associated with placement in these long-term care facilities.

Our results are supported by those from prior studies of sleep and nursing home placement that used retrospective report from caregivers to measure sleep disturbance.[4, 5] On the other hand, our results are only partially consistent with those from prior prospective studies. For example, a prospective investigation in older adults with Alzheimer's disease found that insomnia was associated with a seven-fold increase in the odds of nursing home placement.[6] However, a prospective study of a representative sample of 1,855 older adults found that men, but not women, reporting frequent insomnia or no insomnia had more than five times the risk of nursing home placement than those with occasional insomnia,[7] and a third prospective study of more than 9,000 older adults found no association between sleep disturbance and nursing home placement.[1] Discrepancies between prior studies' findings and our results could have multiple sources, including characteristics of the populations sampled (e.g., age, sex, cognitive status of participants) and use of self-report vs. objective sleep measures.

To our knowledge, the present investigation is the first to evaluate the prospective association between objectively measured sleep and subsequent institutionalization in community-dwelling older adults. As such, it provides evidence for a link between sleep disturbance at time A and long-term care placement at time B, without the limitations of subjective sleep assessment. As mentioned above, results of self-reported and objective sleep measures do not necessarily agree.[8] A variety of factors can contribute to this discordance, including psychopathology,[14, 15] and cognitive deficits. The elevated prevalence of cognitive impairment among older adults, relative to younger populations, makes the use of objective sleep assessment especially important in studies of later-life sleep disturbance.

Although further research is required to replicate our results, our findings could have important implications for the maintenance of independence and quality of life in older adults. Because sleep disturbance can be treated in older adults,[16] additional evidence for a potential causal association between fragmented or inefficient sleep and nursing or personal care home placement would justify the conduct of prevention trials, to investigate the impact of improving sleep on functional trajectories and rates of institutionalization.

In addition, recent findings indicate that such prevention trials need not be limited to community-dwelling women. Martin et al., in a study of residents of assisted living facilities, found that lower sleep SE, as measured by actigraphy, predicted decline in ADLs in a time frame of only three to six months.[17] The authors recommended that interventions

to improve sleep in these residents be developed, and that researchers evaluate their impact on a range of outcomes, including functional trajectories and nursing home placement.[17]

A number of explanations can be applied to our findings of an association between sleep fragmentation and subsequent placement in a nursing or personal care home. First, it is possible that both disrupted, inefficient sleep and the functional decline that necessitates placement in a nursing or personal care home are the result of the same neurodegenerative process, such as Alzheimer's disease. If this were true, sleep disturbance would not be causally related to institutionalization, but it might serve a useful prognostic purpose. If further research supports our findings, clinicians working with older adults might choose to more closely monitor patients exhibiting highly fragmented or inefficient sleep, in an attempt to prevent nursing or personal home placement. A second potential explanation is that caregiver stress, resulting from a lack of nocturnal sleep in their care recipients, prompted institutionalization of our participants. However, McCurry et al. have demonstrated that sleep disturbance in individuals with AD is not consistently associated with disturbed sleep in caregivers.[18] Third, sleep loss has been linked to increases in inflammatory markers.[19] Because inflammation has, in turn been linked to lower levels of physical function in older adults,[20] disturbed sleep might lead to loss of independence by promoting inflammation. Finally, although we adjusted for a range of potential confounders, imperfect measurement of these constructs or unmeasured variables might have led to residual confounding.

The present study had a number of strengths, including a large, well-characterized sample of community-dwelling older women and actigraphic sleep assessment. On the other hand, it included a mostly white sample that consisted entirely of women. Future studies are needed that evaluate the risk of institutionalization conferred by sleep disturbance in more diverse samples of older adults. Although SOF participants reported whether or not they lived with others (e.g., a spouse), they did not complete a measure of social support at this study's baseline or follow-up visits. Thus, we were unable to evaluate the extent to which a lack of social support might have explained our findings. Further, our outcomes of nursing home and personal care home placement were based on participant or informant report, rather than documentation through Medicare records. Use of Medicare data might increase the validity of outcome assessment. Finally, sleep-disordered breathing is associated with sleep fragmentation, and might therefore account for some of the association between sleep fragmentation and institutionalization. Polysomnography data (from which estimates of sleep-disordered breathing are derived) were available for only a subset of our sample, so we did not include it in our analyses. Additional studies are needed to investigate the extent to which sleep fragmentation due to sleep-disordered breathing accounts for the association between fragmented sleep and institutionalization among older adults.

CONCLUSION

Taken together, results indicate that, among community-dwelling older women, greater sleep fragmentation is associated with an increased odds of placement in a nursing home or personal care home five years later, after accounting for a number of potential confounders. Further research is needed to identify the mechanisms linking sleep disturbance to loss of independence in this population, and to determine whether improving sleep—especially sleep continuity—in older adults decreases the risk of institutionalization.

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Table 1

Descriptive Statistics (Mean ± Standard Deviation) for Actigraphic Sleep Parameters.

	Full Sample	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Total sleep time (minutes)	408.4 ± 72.1	493.7 ± 35.5	433.1 ± 11.7	390.8 ± 13.6	316.3 ± 50.1
N	1,664	415	417	415	417
Wake after sleep onset (minutes)	71.3 ± 43.0	29.4 ± 7.8	50.9 ± 5.7	74.1 ± 8.1	131.3 ± 38.1
N	1,663	417	416	416	414
Sleep efficiency (%)	78.6 ± 10.9	89.3 ± 2.4	83.5 ± 1.4	77.5 ± 2.1	63.9 ± 10.3
N	1,664	416	416	416	416

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Table 2

Participant Characteristics (Mean ±Standard Deviation or *n* (%)) at Baseline, across Sleep Efficiency Quartiles.

	Sleep Efficiency				
	Quartile 1 (highest)	**Quartile 2**	**Quartile 3**	**Quartile 4 (lowest)**	***p*-value**
	***n* = 416**	***n* = 416**	***n* = 416**	***n* = 416**	
Age	82.9 ±3.1	83.3 ±3.4	82.9 ±3.6	82.8 ±3.9	0.340
Non-white	21 (5.1)	26 (6.3)	54 (13.0)	78 (18.8)	<0.001
Education > high school	154 (37.0)	156 (37.5)	167 (40.1)	147 (35.4)	0.563
Lives with others	164 (39.4)	175 (42.1)	158 (38.0)	180 (236)	0.389
Lives with spouse	117 (71.3)	126 (72.0)	105 (66.5)	115 (63.9)	0.299
# of IADL or mobility impairments	0.9 ±1.4	1.2 ±1.6	1.2 ±1.6	1.6 ±1.9	<0.001
BMI (kg/m^2)	26.4 ±4.4	26.8 ±4.5	27.7 ±5.1	28.5 ±5.1	<0.001
Current smoker	12 (2.9)	6 (1.4)	10 (2.4)	9 (2.2)	0.557
Alcohol use (drinks/week)	1.0 ±2.5	1.0 ±2.3	0.9 ±2.5	1.2 ±3.5	0.814
Caffeine intake (g/day)	0.2 ±0.1	0.2 ±0.2	0.2 ±0.2	0.2 ±0.2	0.872
Walks for exercise	167 (40.4)	170 (41.1)	167 (40.7)	153 (37.1)	0.634
MMSE score (0–30)	28.4 ±1.6	28.4 ±1.6	28.1 ±1.8	27.8 ±2.2	<0.001
GDS (0–15)	2.0 ±2.4	1.8 ±2.2	2.2 ±2.5	2.6 ±2.6	<0.001
Goldberg Anxiety Scale (0–9)	1.2 ±2.1	1.7 ±2.0	1.5 ±2.3	1.6 ±2.4	0.012
Antidepressant use	46 (11.1)	37 (8.9)	44 (10.6)	71 (17.1)	0.002
Benzodiazepine use	30 (7.2)	29 (7.0)	28 (6.8)	38 (9.1)	0.541
Diabetes	39 (9.4)	32 (7.7)	42 (10.1)	58 (13.9)	0.024
Hypertension	240 (57.7)	228 (54.8)	254 (61.1)	265 (63.7)	0.050
Coronary artery disease	58 (13.9)	70 (16.8)	90 (21.6)	79 (19.0)	0.028
Congestive heart failure	23 (5.5)	32 (7.7)	19 (4.6)	38 (9.1)	0.037
COPD	34 (8.2)	42 (10.1)	55 (13.2)	59 (14.2)	0.023
Osteoarthritis	168 (40.4)	144 (34.6)	175 (42.1)	163 (39.2)	0.148
Stroke	40 (9.6)	40 (9.6)	43 (10.3)	56 (13.5)	0.224
Alzheimer’s disease	2 (0.5)	2 (0.5)	7 (1.7)	9 (2.2)	0.051

Note: *N* ranges from 1,605 to 1,664 for all variables except for living with spouse (*N* = 677).

p-values are from Kruskal-Wallis tests (with rank ties) for continuous variables, χ^2 tests or Fisher's exact tests for categorical variables. BMI = body mass index; COPD = chronic obstructive pulmonary disease; GDS = Geriatric Depression Scale; MMSE = Mini-Mental State Examination.

Table 3

Associations between Actigraphic Sleep Parameters and Nursing Home Placement.

Sleep parameters	*n* (%) placed in nursing home	Unadjusted OR (95% CI)	MV-adjusted* OR (95% CI)
Total sleep time			
Quartile 1 (longest)	18 (4.8)	(ref)	(ref)
Quartile 2	12 (3.1)	0.63 (0.30, 1.33)	0.66 (0.27, 1.57)
Quartile 3	20 (5.2)	1.09 (0.57, 2.10)	1.40 (0.66, 2.95)
Quartile 4 (shortest)	21 (5.4)	1.14 (0.60, 2.18)	1.36 (0.65, 2.84)
p-value for trend		$p = 0.371$	$p = 0.166$
Wake after sleep onset			
Quartile 1 (least)	12 (3.0)	(ref)	(ref)
Quartile 2	10 (2.6)	0.86 (0.37, 2.00)	0.84 (0.33, 2.17)
Quartile 3	19 (5.0)	1.69 (0.81, 3.53)	1.34 (0.57, 3.14)
Quartile 4 (most)	30 (8.0)	2.80 (1.41, 5.55)	2.94 (1.34, 6.44)
p-value for trend		$p < 0.001$	$p = 0.004$
Sleep efficiency			
Quartile 1 (highest)	9 (2.3)	(ref)	(ref)
Quartile 2	13 (3.4)	1.48 (0.62, 3.49)	1.49 (0.58, 3.84)
Quartile 3	22 (5.7)	2.59 (1.18, 5.71)	2.47 (1.01, 6.07)
Quartile 4 (lowest)	27 (7.2)	3.31 (1.54, 7.14)	3.25 (1.35, 7.82)
p-value for trend		$p < 0.001$	$p = 0.004$

Note: $N = 1{,}536$–$1{,}537$ for unadjusted, $N = 1{,}468$ for adjusted analyses.

*Adjusted for age, race (white/non-white), body mass index, Mini-Mental State Examination score, number of IADL/mobility impairments, 15-item Geriatric Depression Scale score, Alzheimer's disease, congestive heart failure, osteoarthritis, antidepressant use, benzodiazepine use. CI = confidence interval; MV = multivariable; OR = odds ratio.

Table 4

Associations between Actigraphic Sleep Parameters and Placement in a Personal Care Home.

Sleep parameters	*n* (%) placed in a personal care home	Unadjusted OR (95% CI)	MV-adjusted* OR (95% CI)
Total sleep time			
Quartile 1 (longest)	39 (9.8)	(ref)	(ref)
Quartile 2	27 (6.7)	0.66 (0.39, 1.09)	0.79 (0.45, 1.36)
Quartile 3	31 (7.9)	0.78 (0.48, 1.28)	1.05 (0.62, 1.78)
Quartile 4 (shortest)	30 (7.6)	0.75 (0.46, 1.24)	0.95 (0.55, 1.64)
p-value for trend		$p = 0.403$	$p = 0.881$
Wake after sleep onset			
Quartile 1 (least)	20 (4.9)	(ref)	(ref)
Quartile 2	31 (7.6)	1.59 (0.89, 2.84)	1.68 (0.91, 3.10)
Quartile 3	36 (9.1)	1.92 (1.09, 3.38)	2.14 (1.17, 3.91)
Quartile 4 (most)	40 (10.4)	2.24 (1.28, 3.90)	2.33 (1.26, 4.30)
p-value for trend		$p = 0.003$	$p = 0.005$
Sleep efficiency			
Quartile 1 (highest)	24 (5.9)	(ref)	(ref)
Quartile 2	28 (7.0)	1.19 (0.68, 2.09)	1.36 (0.74, 2.49)
Quartile 3	33 (8.4)	1.46 (0.85, 2.52)	1.66 (0.92, 3.00)
Quartile 4 (lowest)	42 (10.8)	1.93 (1.15, 3.26)	2.38 (1.33, 4.24)
p-value for trend		$p = 0.010$	$p = 0.003$

Note: $N = 1{,}592$–$1{,}593$ for unadjusted, $N = 1{,}525$ for adjusted analyses.

*Adjusted for age, race (white/non-white), body mass index, Mini-Mental State Examination score, number of IADL/mobility impairments, 15-item Geriatric Depression Scale score, Alzheimer's disease, congestive heart failure, osteoarthritis, antidepressant use, benzodiazepine use. CI = confidence interval; MV = multivariable; OR = odds ratio.