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SCIENTIFIC INVESTIGATIONS

Self-reported and actigraphic short sleep duration in older adults

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Study Objectives: Persons > 65 years with short sleep duration (≤ 6 hours) are at risk for adverse outcomes, but the accuracy of self-reported sleep duration may be affected by reduced symptom awareness. We evaluated the performance characteristics of self-reported vs objectively measured sleep duration in this age group.

Methods: In 2,980 men from the Osteoporotic Fractures in Men Sleep Study and 2,855 women from the Study of Osteoporotic Fractures we examined the agreement and accuracy of self-reported vs actigraphy-measured short and normal (> 6 but < 9 hours) sleep duration. We evaluated associations of select factors (demographics; medical, physical, and neuropsychiatric conditions; medication and substance use; and sleep-related measures) with risk of false-negative (normal sleep duration by self-report but short sleep duration by actigraphy) and false-positive (short sleep duration by self-report and normal sleep duration by actigraphy) designations, respectively, using logistic regression.

Results: Average ages were 76.3 ± 5.5 and 83.5 ± 3.7 years in men and women, respectively. There was poor agreement between self-reported and actigraphic sleep duration (kappa ≤ 0.24). False negatives occurred in nearly half and false positives in over a quarter of older persons. In multivariable models in men and women, false negatives were independently associated with obesity, daytime sleepiness, and napping, while false positives were significantly lower with obesity.

Conclusions: Under- and overreporting of short sleep is common among older persons. Reliance on self-report may lead to missed opportunities to prevent adverse outcomes or unnecessary interventions. Self-reported sleep duration should be objectively confirmed when evaluating the effect of sleep duration on health outcomes.

Keywords: aging, sleep duration, actigraphy, sleep disorders

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BRIEF SUMMARY

Current Knowledge/Study Rationale: Older persons with short sleep duration are at risk for adverse cognitive and functional outcomes, but reduced symptom awareness may affect how they report their sleep. The performance characteristics of self-reported vs objective (actigraphic) measures of short sleep have not been examined in this group.

Study Impact: The accuracy of self-reported compared to actigraphy-measured short sleep duration was poor, with nearly half of older persons having false-negative designations (normal sleep duration by self-report but short sleep by actigraphy) and over 25% having false-positive designations (short sleep duration by self-report and normal sleep duration by actigraphy). Objective confirmation is needed when evaluating the effect of short sleep duration on health outcomes to avoid missed diagnoses or unnecessary interventions.

INTRODUCTION

Short sleep duration, most often defined as 6 hours or less of total overnight sleep, is a strong risk factor for mortality as well as adverse cardiovascular, metabolic, immunologic, cognitive, and functional outcomes.[1–4] Older persons are a particularly vulnerable group since they are already at risk for aging-related declines in cognition and physical function, which may worsen as a result of short sleep duration.[5,6] Thus, identifying older persons with short sleep duration may allow us to recognize a high-risk group in need of further assessment and treatment.

In the clinical setting, sleep duration is usually assessed by self-report. However, a growing body of research suggests that the accuracy of self-report in older persons may be affected by reduced symptom awareness.[7] Older persons report milder levels of insomnia and daytime sleepiness than younger persons, despite having more severe sleep disorders.[8] Given concerns about reduced symptom awareness in older persons, there is a need to evaluate the performance characteristics of self-reported short sleep duration as compared to objective sleep measures and to determine whether age-related factors are associated with disagreement between these measures. Prior work has shown poor agreement between self-reported and objective measures of sleep duration in various populations.[9–11] However, the frequency and direction of disagreement (ie, false-negative or "overestimation" vs false-positive

or "underestimation" of self-reported as compared to objective sleep duration) and characteristics associated with these disagreements have received little attention, especially among older adults (ie, after the eighth decade of life).

In the current study, using two well-established cohorts,[12–14] we evaluated agreement between self-reported and objectively (actigraphy) measured short (≤ 6 hours) and normal (> 6 but < 9 hours) sleep duration in community-dwelling older men and women, respectively, and identified factors that were associated with disagreement. These factors, which may contribute to short sleep duration and/or modify sleep–wake awareness, include demographics, medical comorbidities, physical impairments, neuropsychiatric conditions, medication and substance use, and sleep-related impairments. Because of reduced symptom awareness, we hypothesized that agreement between self-reported and actigraphic short sleep duration would be poor and that several clinical factors would be associated with disagreement. The results of our study may inform methods of evaluating short sleep duration in older persons.

METHODS

Study population

This is a secondary analysis of cross-sectional data from the Osteoporotic Fractures in Men (MrOS) Sleep Study and the Study of Osteoporotic Fractures (SOF).[12–14] For both studies, inclusion criteria were age ≥ 65 years and ability to ambulate without the assistance of another person.[12–14] The study protocols were approved by the institutional review boards at all participating centers and included written informed consent.

The investigators for MrOS recruited 5,994 community-dwelling men from 2000–2002 at six clinical centers in the United States.[12,13] The MrOS Sleep Study, an ancillary study conducted from 2003–2005, recruited 3,135 participants for a comprehensive sleep assessment. The sleep assessment included an in-clinic interview with validated sleep questionnaires, a series of clinical measures, wrist actigraphy, and overnight in-home polysomnography (PSG). The men had wrist actigraphy for an average of 5 days. Of the 3,135 men who participated in the comprehensive sleep assessment, 3,055 (97.4%) had usable actigraphy (see **Figure S1** in the supplemental material).

SOF was a prospective cohort study of community-dwelling older women from four geographic areas in the United States.[14] From 1986 to 1988, 9,704 Caucasian participants were recruited into the original cohort. From 1997 to 1998, 662 African American women were purposefully recruited to increase diversity. A comprehensive sleep assessment was performed (2002–2004). This assessment included an in-clinic interview with validated sleep questionnaires, clinical measures, and a minimum of 3 days of wrist actigraphy. Of the 3,676 women who had clinic or in-home visits, 3,052 (83.0%) had usable actigraphy (see **Figure S2** in the supplemental material).

For our analytical samples, we included only those participants with short or normal sleep duration, as defined by self-report or actigraphy. Participants with self-reported or actigraphic long sleep duration (> 9 hours) could not be examined separately due to small sample sizes and were excluded from the normal sleep duration group given the association of long sleep duration with adverse health outcomes.[1] In MrOS, of the 3,055 men with usable actigraphy, 75 (2.4%) were excluded (44 had long sleep duration by self-report, 29 had long sleep duration by actigraphy, and 2 had missing data on self-reported sleep duration), yielding a final analytical sample of n = 2,980. In SOF, of the 3,052 women with usable actigraphy, 197 (6.9%) were excluded (105 had long sleep duration by self-report, 84 had long sleep duration by actigraphy, and 8 had missing data on self-reported sleep duration), yielding a final analytical sample of n = 2,855.

Demographic and clinical characteristics

Demographic information included age, race, education level (< high school education vs other), living situation (living alone vs other), and marital status (widowed vs other). Medical conditions included obesity (body mass index ≥ 30 kg/m^2), self-reported conditions available in men and women (diabetes mellitus, osteoarthritis, chronic obstructive pulmonary disease, hypertension, myocardial infarction, congestive heart failure [CHF], and stroke), ≥ 3 chronic conditions[15] (based on a count of the 7 self-reported conditions), and benign prostatic hypertrophy (in men only). Physical characteristics were evaluated objectively and included physical impairment (gait speed < 0.8 m/s at participant's usual pace),[16] vision impairment (worse than 20/40 on the Bailey-Lovie test of visual acuity),[17] and physical inactivity (percent actigraphy wear time during the day with activity < 5,000 counts/min [see **Validation of Definition of Sedentary Behavior Based on Actigraphy Data** in the supplemental material], averaged over all days of monitoring, including at least 10 hours on each day).[18] Neuropsychiatric conditions included depression (Geriatric Depression Scale ≥ 6),[19] anxiety (Goldberg Anxiety Scale score > 5),[20] and cognitive impairment (Modified Mini-Mental Status Examination score 1.5 standard deviations below the cohort-specific mean [≤ 22 in MrOS and ≤ 21 in SOF]).[21,22] All prescription and nonprescription medications used within the preceding 30 days were entered into an electronic database; each medication was matched to its ingredient(s) based on the Iowa Drug Information Service Drug Vocabulary (College of Pharmacy, University of Iowa, Iowa City, IA).[23] Medications included use of an antidepressant (tricyclics, selective serotonin reuptake inhibitors, serotonin-norepinephrine reuptake inhibitors, or trazodone)[24] and use of a central nervous system–active medication (benzodiazepines, anticonvulsants, narcotics, or antipsychotics).[24] Substance use included alcohol (drinks per week), caffeine intake ≥ 190 mg/d (ie, the equivalent of at least two cups of coffee),[25] and current smoking.

Sleep-related measures included self-reported sleep quality, daytime sleepiness, napping, restless legs syndrome, and sleep-disordered breathing (SDB; in men only). Self-reported sleep quality was evaluated by Pittsburgh Sleep Quality Index (PSQI) item 9 ("During the past month, how would you rate your sleep quality overall?"), with scores ranging from 0 (very good) to 3 (very bad).[26] Poor sleep quality was defined by a score > 1 (ie, fairly bad or very bad) on PSQI item 9. Because an additional item from the PSQI was used to define self-reported sleep duration (see the section on sleep duration below) we did not use

total PSQI score to evaluate sleep quality. Daytime sleepiness was evaluated by the Epworth Sleepiness Scale (ESS).[27] The ESS score ranges 0–24, with higher scores indicating more severe daytime sleepiness. An ESS score > 10 is a validated cut-off for patient-reported hypersomnia associated with adverse health outcomes in older persons.[27] Restless legs syndrome was established by self-report of a physician diagnosis. SDB was established in MrOS by an apnea-hypopnea index (at ≥ 4% desaturation) per hour of sleep ≥ 15 on PSG.[28] A polysomnographic assessment for the presence of SDB was available in a convenience sample of n = 461 (16.1%) women. Given the large amount of missing data for this variable, which were not missing at random, multiple imputation was not possible. Thus, we examined bivariate associations of SDB in n = 461 women from SOF with false-negative and false-positive designations, respectively (described under statistical analysis). We did not include SDB in multivariable models in SOF, which allowed us to have a larger sample with which to evaluate a greater number of clinical correlates.

Sleep duration

Overnight sleep duration was defined as normal (> 6 but < 9 hours) or short (≤ 6 hours), based on the joint consensus statement from the American Academy of Sleep Medicine and the Sleep Research Society on the recommended amount of sleep for a healthy adult.[29] Our operational definition for short sleep duration is supported by several reports among older persons that have demonstrated adverse outcomes (mortality, impaired cognition, and impaired functional capacity) with sleep durations at or below 6 hours.[2–4,30] In addition, the average sleep duration, whether self-reported or measured by actigraphy, was below 7 hours in men and women (as shown in **Table S1** in the supplemental material), supporting use of a lower cutoff in our study population. Self-reported duration was assessed using PSQI item 4a: "During the past month, how many hours of actual sleep did you get at night?".[26] In MrOS and SOF, PSQI forms required participants to provide an integer response for estimated sleep duration.

Objective sleep duration was evaluated by wrist actigraphy. While PSG is the gold standard for measurement of sleep, meta-analyses of PSG vs actigraphy have shown narrow ranges in the mean difference in sleep duration between these two measures,[31] with actigraphy overestimating sleep duration by 13–18 minutes on average in older men and women.[32,33] In addition, the American Academy of Sleep Medicine suggests that actigraphy is appropriate for estimation of sleep duration in a variety of sleep disorders.[31] Participants in MrOS and SOF wore the SleepWatch-O actigraph (Ambulatory Monitoring, Inc., Ardsley, New York) on the nondominant hand. Average use (standard deviation) was 5.2 (0.9) nights in MrOS and 4.1 (0.8) nights in SOF. Actigraph data were analyzed using Action W-2 software with proportional integration mode and the University of California San Diego scoring algorithm.[34] Full details of the validation of these methods have been published previously.[32,33] The software algorithm and sleep diaries were used to edit the raw data and generate variables for different sleep measures, including sleep duration.[32,33] Prior analyses of actigraphy data from SOF and MrOS have shown high inter-scorer reliability.[32,33] In both the MrOS and SOF studies, 95% of participants initiated their actigraphy recordings within a week of completing the PSQI.

Statistical analysis

MrOS (men) and SOF (women) were evaluated separately but in parallel fashion due to differences in clinical characteristics and availability of PSG-measured SDB. Distributions of clinical characteristics were summarized as means (± standard deviations) or frequencies (%). Frequency distributions for normal and short sleep duration were calculated according to measurement method (self-report or actigraphy; actigraphic sleep duration was recorded in minutes and was rounded to the nearest hour for comparison with self-reported sleep duration). Considering actigraphy as the gold standard, we calculated the frequency of four groups: (1) true negatives (normal sleep duration by self-report and actigraphy), (2) false negatives (normal sleep duration by self-report but short sleep duration by actigraphy), (3) true positives (short sleep duration by self-report and actigraphy), and (4) false positives (short sleep duration by self-report and normal sleep duration by actigraphy). Characteristics of participants were compared by group using chi-square tests for homogeneity for categorical variables and analysis of variance for normally distributed continuous variables.

Next, the kappa coefficient was calculated to examine the degree of agreement between self-reported and actigraphic measures of short sleep duration. With actigraphy serving as the reference standard, the sensitivity, false-negative rate, specificity, false-positive rate, positive predictive value, negative predictive value, and accuracy (ie, the proportion of true positives and true negatives in all evaluated cases) of self-reported sleep duration were calculated. The primary analyses used a duration ≤ 6 hours to define short sleep. In sensitivity analyses, we used a duration ≤ 7 hours (see **Table S2** in the supplemental material). Concordance between continuous measures of self-reported and actigraphic sleep duration was analyzed with the estimate and 95% confidence interval of the two-way fixed-effects intraclass correlation coefficient for absolute agreement. Bland-Altman plots with 95% limits of agreement were presented to display the distribution of differences between the two measures of sleep duration and to assess systematic bias in these differences.[35] Formal tests of systematic bias were performed using simple linear regression models to examine whether the scatter in the Bland-Altman plots was heteroscedastic.[36]

Using logistic regression, we calculated the odds of a false-negative or a false-positive designation. False-negative designations (normal sleep duration by self-report but short sleep [≤ 6 hours] duration by actigraphy) were evaluated among the subgroup of men and women who reported normal sleep duration (1,996 men and 1,626 women). The reference group for these models included those with a true-negative designation (normal sleep duration by self-report and actigraphy). False-positive designations (short sleep duration by self-report and normal sleep duration by actigraphy) were evaluated among the subgroup of men and women who reported short sleep

duration (984 men and 1,229 women). The reference group for false-positive designations included those with a true-positive designation (short sleep duration by self-report and actigraphy). In bivariate analyses, logistic regression models estimated unadjusted odds ratios (ORs) and 95% confidence intervals of a false-negative or a false-positive designation for each demographic and clinical characteristic (see **Table S3** and **Table S4** in the supplemental material). Multivariate models, derived using backward selection with a requirement of a P value ≤ .20 to remain in the model, estimated adjusted ORs (adjORs) and 95% confidence intervals of a false-negative or a false-positive designation. This methodology was chosen based on the large number of variables examined and the exploratory nature of the analysis. Age, race, and education level were kept in all models regardless of P value due to their known associations with sleep duration and self-reported sleep.[37] For verification purposes, we also performed forward selection with a P value ≤ .20 for entry into the model, which displayed similar results (data not shown). Model fit was inspected using collinearity diagnostics and residual plots. All analyses were conducted using SAS version 9.4 software (SAS Institute Inc., Cary, NC).

RESULTS

As compared with SOF, MrOS participants were younger (average ages were 76.3 ± 5.5 and 83.5 ± 3.7 years in men and women, respectively), more educated, and less likely to live alone or be widowed; reported fewer comorbidities, physical impairments, and neuropsychiatric conditions; and had less medication use. Actigraphy-measured short sleep was more prevalent in MrOS (32.4% and 26.1% in men and women, respectively), while self-reported short sleep was more prevalent in SOF (33% and 43.1% in men and women, respectively) (see **Table S1**).

Table 1 and **Table 2** show clinical characteristics of MrOS (men) and SOF (women), respectively, for the four groups, where false negatives represent normal sleep duration by self-report but short sleep duration by actigraphy and false positives represent short sleep duration by self-report but normal sleep duration by actigraphy. Among men, sociodemographic factors (race, education, living alone, marital status), medical factors (obesity, diabetes mellitus, CHF, ≥ 3 chronic conditions), physical impairment, neuropsychiatric factors (depression, anxiety), medication and substance use (central nervous system–active medications, alcohol use, caffeine intake), and sleep-related factors (PSQI item 9 score > 1, ESS score > 10, daily napping, restless legs syndrome, SDB) differed significantly across the four groups. Among women, significant differences across the four groups were observed for sociodemographic factors (age, race, education), medical factors (obesity, chronic obstructive pulmonary disease, hypertension, CHF, ≥ 3 chronic conditions), physical impairment, neuropsychiatric factors (depression, anxiety, cognitive impairment), medication use (antidepressant), and sleep-related factors (PSQI item 9 score > 1, ESS score > 10, daily napping, restless legs syndrome).

Table 3 shows the agreement and accuracy of self-reported vs actigraphy-measured short sleep. Kappa statistics were low in men and women (0.24 and 0.15, respectively), indicating poor to no agreement. Using actigraphy as the reference standard, the sensitivity of self-reported short sleep was poor in both sexes (0.49 and 0.57 in men and women, respectively), leading to false-negative rates of 50.9% in men and 43.4% in women. Positive predictive values were also low for both sexes (0.48 and 0.34 in men and women, respectively), with false-positive rates of 25.3% in men and 38.3% in women. Otherwise, specificity and negative predictive values were fair to good in men and women. Overall accuracy was 0.66 in men and 0.60 in women, below the acceptable range for model discrimination.[38] When a cutoff of ≤ 7 hours was used to define short sleep duration in men and women, kappa statistics showed similarly poor agreement. Sensitivity increased in both cohorts, while specificity decreased, and overall accuracy did not change substantially (see **Table S2**).

Figure 1 shows Bland-Altman plots comparing continuous measures of self-reported and actigraphic sleep duration in MrOS (**Figure 1A**) and SOF (**Figure 1B**). Mean differences do not appear to vary by the size of the average value of the two sleep measures. However, both plots display wide 95% limits of agreement, outside of a range that would be considered clinically negligible. In addition, the Bland-Altman plot for MrOS shows a fixed systematic bias for overestimation of self-reported sleep duration to actigraphy of 33 minutes (P < .001). The Pearson correlation coefficients for continuous measures of self-reported and actigraphic sleep duration were poor (0.30 in MrOS and 0.21 in SOF). The intraclass correlation coefficients and corresponding confidence intervals for agreement of the self-reported and actigraphic measures of sleep duration were 0.22 (0.19, 0.26) and 0.20 (0.17, 0.24) respectively, indicating poor reliability. Using a consistency measure, which accounts for bias, the intraclass correlation coefficient for the MrOS sample increased to 0.26.

Table 4 and **Table 5** show the adjORs after backward selection for correlates of a false-negative designation, relative to a true-negative designation (normal sleep duration by self-report and actigraphy). Multivariable models in MrOS and SOF were adjusted for all clinical characteristics shown in **Table 1** and **Table 2**, respectively. As shown in **Table 4**, the adjOR of a false-negative designation was significantly higher in men who were widowed, obese, had a history of CHF, had daytime sleepiness, were daily nappers, and had SDB (adjORs of 1.56–2.34). The adjusted odds of a false-negative designation were significantly lower in men with a history of stroke or physical inactivity (adjORs 0.42–0.79). As shown in **Table 5**, the adjOR of a false-negative designation was significantly higher in women with obesity, physical impairment, daytime sleepiness, and daily napping (adjORs of 1.62–1.93) but significantly lower in women with depression or low physical activity (adjORs 0.56–0.85). In bivariate associations, the unadjusted OR for a false-negative designation in women with SDB was 1.68 (0.88, 3.22).

Table 6 and **Table 7** show adjORs after backward selection of a false-positive designation, relative to a true-positive designation (short sleep by self-report and actigraphy). As shown in **Table 6**, the adjOR of a false-positive designation was significantly higher in men with poor sleep quality (adj OR 1.39 [1.03, 1.86]) and significantly lower in men with obesity, daily napping,

Table 1—Clinical characteristics in MrOS (men) according to sleep category.

Characteristics	True Negatives (n = 1,504)	False Negatives (n = 492)	True Positives (n = 474)	False Positives (n = 510)	P[a]
Sociodemographics					
Age, y	79.4 ± 5.6	76.7 ± 5.6	76.1 ± 5.4	76.0 ± 5.3	.155
Non-White race	115 (7.6)	44 (8.9)	79 (16.7)	58 (11.4)	<.001
Less than high school education	60 (4.0)	26 (5.3)	40 (8.4)	30 (5.9)	.002
Living alone	179 (11.9)	75 (15.3)	85 (18.1)	59 (11.7)	.002
Widowed	114 (7.6)	58 (11.8)	55 (11.7)	38 (7.5)	.003
Medical					
Obesity[b]	244 (16.2)	151 (30.7)	134 (28.3)	78 (15.3)	<.001
Diabetes[c]	170 (11.3)	79 (16.1)	70 (14.8)	70 (13.7)	.024
Osteoarthritis[c]	329 (21.9)	124 (25.2)	124 (26.2)	129 (25.3)	.124
COPD[c]	68 (4.5)	26 (5.3)	33 (7.0)	31 (6.1)	.169
Hypertension[c]	716 (47.6)	249 (50.6)	247 (52.1)	273 (53.5)	.076
Myocardial infarction[c]	249 (16.6)	75 (15.2)	94 (19.8)	99 (19.4)	.126
CHF[c]	60 (4.0)	42 (8.5)	46 (9.7)	38 (7.5)	<.001
Stroke[c]	58 (3.8)	9 (1.8)	21 (4.4)	23 (4.5)	.088
BPH[c]	708 (47.1)	224 (45.6)	240 (50.9)	263 (51.9)	.110
≥ 3 Chronic conditions[d]	144 (9.6)	59 (12.0)	72 (15.2)	69 (13.5)	.003
Physical					
Physical impairment[e]	82 (5.5)	42 (8.7)	40 (8.6)	34 (6.7)	.026
Vision impairment[f]	50 (3.3)	24 (4.9)	17 (3.6)	19 (3.7)	.475
Physical inactivity[g]	68.2 ± 11.0	67.2 ± 11.5	67.9 ± 11.3	68.9 ± 11.5	.131
Neuropsychiatric					
Depression[h]	70 (4.7)	30 (6.1)	42 (8.9)	51 (10.0)	<.001
Anxiety[i]	80 (5.3)	27 (5.5)	74 (15.7)	88 (17.3)	<.001
Cognitive impairment[j]	165 (11.0)	61 (12.4)	71 (15.0)	68 (13.3)	.105
Medication and substance use					
Antidepressant[k]	117 (7.8)	32 (6.5)	32 (6.8)	46 (9.0)	.415
CNS-active medication[l]	136 (9.0)	61 (12.4)	60 (12.7)	66 (12.9)	.017
Alcohol (drinks per week)	3.7 ± 4.3	3.4 ± 4.2	3.3 ± 4.2	2.9 ± 3.9	<.001
Caffeine intake ≥ 190 mg/d	677 (45.0)	251 (51.0)	240 (50.6)	219 (42.9)	.011
Current smoking	25 (1.7)	10 (2.0)	17 (3.6)	10 (2.0)	.085
Sleep-related factors					
Self-reported sleep duration[m]	7.6 ± 0.6	7.5 ± 0.6	5.5 ± 0.7	5.6 ± 0.7	<.001
Actigraphic sleep duration[n]	7.1 ± 0.7	5.1 ± 0.9	5.0 ± 0.9	6.8 ± 0.6	<.001
Poor sleep quality[o]	92 (6.1)	43 (8.7)	147 (31.0)	182 (35.7)	<.001
Daytime sleepiness[p]	152 (10.1)	80 (16.3)	85 (18.0)	69 (13.5)	<.001
Daily napping	163 (10.8)	109 (22.2)	106 (22.4)	75 (14.7)	<.001
RLS[c]	19 (1.3)	15 (3.1)	15 (3.3)	16 (3.2)	.007
SDB[q]	308 (21.7)	165 (35.7)	145 (33.7)	119 (24.7)	<.001

Values are presented as mean ± SD or n (%). Those with long sleep duration (> 9 hours on self-report or actigraphy; n = 73 men) were excluded. True negative = normal sleep duration by self-report and actigraphy, false negative = normal sleep duration by self-report but short sleep duration by actigraphy, true positive = short sleep duration by self-report and actigraphy, false positive = short sleep duration by self-report and normal sleep duration by actigraphy. [a]Derived from one-way analysis of variance for continuous variables and chi-square test for categorical variables comparing the 4 groups. [b]Body mass index ≥ 30 kg/m^2. [c]Self-reported, physician-diagnosed. [d]From 7 medical conditions available in men and women (diabetes, osteoarthritis, COPD, hypertension, myocardial infarction, CHF, and stroke). [e]Gait speed < 0.8 m/s. [f]Visual acuity 20/40 or worse. [g]Percent actigraphy wear time with activity < 5,000 counts/min, averaged over all days of monitoring, including 10 hours on each day. [h]Geriatric Depression Scale score ≥ 6. [i]Goldberg Anxiety Scale score > 5. [j]Modified Mini-Mental Status Examination score 1.5 SD below the mean (≤ 22). [k]Includes use of tricyclics, selective serotonin reuptake inhibitors, serotonin reuptake inhibitors, or trazodone. [l]Includes use of benzodiazepines, anticonvulsants, narcotics, or antipsychotics. [m]From PSQI item 4a ("How many actual hours of sleep did you get at night?"). [n]Averaged over 5.2 (0.9) nights in MrOS and 4.1 (0.8) nights in SOF. [o]Self-rated sleep quality over the previous month > 1 (range = 0 [very good] to 3 [very bad]). [p]ESS score > 10. [q]Apnea-hypopnea index ≥ 15. BPH = benign prostatic hypertrophy, CHF = congestive heart failure, CNS = central nervous system, COPD = chronic obstructive pulmonary disease, ESS = Epworth Sleepiness Scale, MrOS = Osteoporotic Fractures in Men Sleep Study, PSQI = Pittsburgh Sleep Quality Index, RLS = restless legs syndrome, SD = standard deviation, SDB = sleep-disordered breathing, SOF = Study of Osteoporotic Fractures.

Table 2—Clinical characteristics in SOF (women) according to sleep category.

Characteristics	True Negatives (n = 1,303)	False Negatives (n = 323)	True Positives (n = 421)	False Positives (n = 808)	P[a]
Sociodemographics					
Age, y	83.7 ± 3.6	83.5 ± 4.1	82.9 ± 3.7	83.4 ± 3.8	.001
African American	93 (7.1)	45 (13.9)	71 (16.9)	93 (11.5)	<.001
Less than high school education	205 (15.7)	62 (19.2)	80 (19.0)	168 (20.8)	.023
Living alone	778 (59.7)	183 (56.7)	268 (63.7)	506 (62.6)	.136
Widowed	797 (61.2)	199 (61.6)	261 (62.0)	512 (63.4)	.791
Medical					
Obesity[b]	278 (21.7)	108 (34.8)	143 (34.6)	178 (22.3)	<.001
Diabetes[c]	128 (9.8)	43 (13.3)	53 (12.6)	93 (11.5)	.184
Osteoarthritis[c]	483 (37.1)	129 (40.0)	180 (42.8)	315 (39.0)	.203
COPD[c]	131 (10.1)	63 (19.5)	58 (13.8)	94 (11.6)	<.001
Hypertension[c]	741 (56.9)	201 (62.2)	269 (63.9)	515 (63.7)	.004
Myocardial infarction[c]	146 (11.2)	43 (13.3)	46 (10.9)	96 (11.9)	.712
CHF[c]	89 (6.8)	41 (12.7)	40 (9.5)	66 (8.2)	.005
Stroke[c]	164 (12.6)	45(13.9)	55 (13.1)	87 (10.8)	.410
≥ 3 chronic conditions[d]	206 (15.8)	82 (25.4)	89 (21.1)	152 (18.8)	<.001
Physical					
Physical impairment[e]	481 (39.0)	148 (51.9)	174 (46.0)	278 (36.8)	<.001
Vision impairment[f]	255 (22.6)	64 (23.6)	75 (20.5)	134 (18.7)	.159
Physical inactivity[g]	66.7 ± 12.9	66.9 ± 14.4	66.8 ± 13.0	66.6 ± 12.3	.989
Neuropsychiatric					
Depression[h]	130 (10.0)	28 (8.7)	57 (13.5)	106 (13.1)	.025
Anxiety[i]	108 (8.3)	20 (6.2)	92 (21.9)	181 (22.5)	<.001
Cognitive impairment[j]	122 (9.8)	40 (13.2)	33 (8.2)	53 (6.7)	.006
Medication and substance use					
Antidepressant[k]	174 (13.4)	53 (16.5)	52 (12.4)	80 (9.9)	.015
CNS-active medication[l]	229 (17.6)	66 (20.4)	85 (20.2)	177 (21.9)	.095
Alcohol (drinks per week)	1.2 ± 2.8	1.1 ± 2.9	1.0 ± 2.7	1.0 ± 2.6	.600
Caffeine intake ≥ 190 mg/d	528 (40.5)	124 (38.4)	151 (35.9)	324 (40.1)	.364
Current smoking	35 (2.7)	14 (4.3)	13 (3.1)	13 (1.6)	.062
Sleep-related factors					
Self-reported sleep duration[m]	7.6 ± 0.7	7.5 ± 0.6	5.5 ± 0.7	5.5 ± 0.7	<.001
Actigraphic sleep duration[n]	7.3 ± 0.7	5.1 ± 0.9	5.1 ± 0.8	7.1 ± 0.7	<.001
Poor sleep quality[o]	55 (4.2)	17 (5.3)	119 (28.3)	259 (32.1)	<.001
Daytime sleepiness[p]	117 (9.0)	52 (16.1)	78 (18.5)	72 (8.9)	<.001
Daily napping	163 (12.5)	67 (20.9)	78 (18.6)	101 (12.5)	<.001
RLS[c]	34 (2.6)	16 (5.0)	23 (5.5)	48 (5.9)	.001

Values are presented as mean ± SD or n (%). Those with long sleep duration (> 9 hours on self-report or actigraphy; n = 189 women) were excluded. True negative = normal sleep duration by self-report and actigraphy, false negative = normal sleep duration by self-report but short sleep duration by actigraphy, true positive = short sleep duration by self-report and actigraphy, false positive = short sleep duration by self-report and normal sleep duration by actigraphy. [a]Derived from one-way analysis of variance for continuous variables and chi-square test for categorical variables comparing the 4 groups. [b]Body mass index ≥ 30 kg/m^2. [c]Self-reported, physician-diagnosed. [d]From 7 medical conditions available in men and women (diabetes, osteoarthritis, COPD, hypertension, myocardial infarction, CHF, and stroke). [e]Gait speed < 0.8 m/s. [f]Visual acuity 20/40 or worse. [g]Percent actigraphy wear time with activity < 5,000 counts/min, averaged over all days of monitoring, including 10 hours on each day. [h]Geriatric Depression Scale score ≥ 6. [i]Goldberg Anxiety Scale score > 5. [j]Modified Mini-Mental Status Examination score 1.5 SD below the mean (≤ 21). [k]Includes use of tricyclics, selective serotonin reuptake inhibitors, serotonin reuptake inhibitors, or trazodone. [l]Includes use of benzodiazepines, anticonvulsants, narcotics, or antipsychotics. [m]From PSQI item 4a ("How many actual hours of sleep did you get at night?"). [n]Averaged over 5.2 (0.9) nights in MrOS and 4.1 (0.8) nights in SOF. [o]Self-rated sleep quality over the previous month > 1 (range = 0 [very good] to 3 [very bad]). [p]ESS score > 10. CHF = congestive heart failure, CNS = central nervous system, COPD = chronic obstructive pulmonary disease, ESS = Epworth Sleepiness Scale, MrOS = Osteoporotic Fractures in Men Sleep Study, PSQI = Pittsburgh Sleep Quality Index, RLS = restless legs syndrome, SD = standard deviation, SDB = sleep-disordered breathing, SOF = Study of Osteoporotic Fractures.

Table 3—Agreement and accuracy of self-reported vs actigraphy-measured short sleep.

	Actigraphy: Short Sleep		
	Yes	**No**	**Total**
A. MrOS (men)			
Self-report: short sleep			
Yes	474 (15.9%)	510 (17.1%)	984 (33.0%)
No	492 (16.5%)	1504 (50.5%)	1,996 (67.0%)
Total	966 (32.4%)	2,014 (67.6%)	2,980 (100%)
Kappa statistic	0.24 (95% CI: 0.20, 0.27)		
Sensitivity	0.49 (95% CI: 0.46, 0.52)		
False-negative rate	50.9% (95% CI: 47.7%, 54.1%)		
Specificity	0.75 (95% CI: 0.73, 0.77)		
False-positive rate	25.3% (95% CI: 23.4%, 27.2%)		
PPV	0.48 (95% CI: 0.45, 0.52)		
NPV	0.75 (95% CI: 0.73, 0.77)		
Accuracy	0.66 (95% CI: 0.65, 0.68)		
B. SOF **(w**omen**)**			
Self-report: short sleep			
Yes	421 (14.7%)	808 (28.3%)	1,229 (43.0%)
No	323 (11.3%)	1,303 (45.6%)	1,626 (57.0%)
Total	744 (26.0%)	2,110 (73.9%)	2,855 (100%)
Kappa statistic	0.15 (95% CI: 0.12, 0.19)		
Sensitivity	0.57 (95% CI: 0.53, 0.60)		
False-negative rate	43.4% (95% CI: 39.8%, 47.1%)		
Specificity	0.62 (95% CI: 0.60, 0.64)		
False-positive rate	38.3% (95% CI: 36.2%, 40.4%)		
PPV	0.34 (95% CI: 0.32, 0.37)		
NPV	0.80 (95% CI: 0.78, 0.82)		
Accuracy	0.60 (95% CI: 0.58, 0.62)		

(A) MrOS (n = 2,980) and **(B)** SOF (n = 2,855). Range of sleep time is 0 to 9 hours, wherein short sleep duration is 0–6 hours and normal sleep duration is > 6 hours (up to 9 hours). CI = confidence interval, MrOS = Osteoporotic Fractures in Men Sleep Study, NPV = negative predictive value, PPV = positive predictive value, SOF = Study of Osteoporotic Fractures.

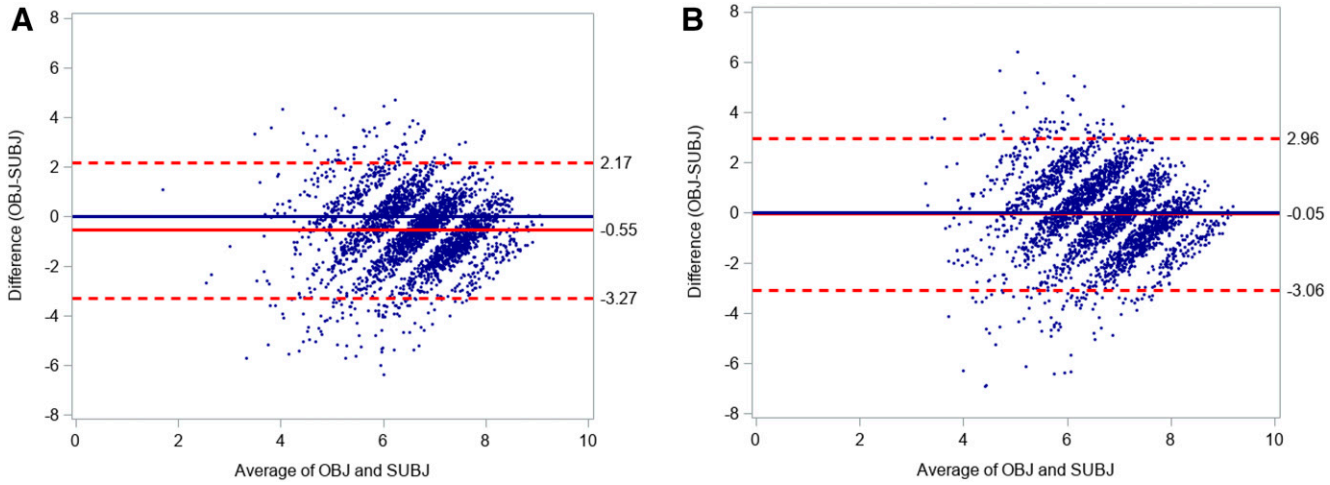
and SDB (adjORs of 0.46–0.68). As shown in **Table 7**, the adjOR of a false-positive designation was significantly higher in women per each additional year of age (adjOR 1.05 [1.01, 1.10]) and significantly lower in women with obesity, physical impairment, and daytime sleepiness (adjOR of 0.46–0.65). In bivariate associations, the unadjusted OR for a false-positive designation in women with SDB was 0.52 (0.28, 0.95).

DISCUSSION

We have described the agreement between self-reported and actigraphic short sleep duration (≤ 6 hours) in two large cohorts of community-dwelling older men (MrOS) and women (SOF). Our results show that there was minimal agreement for short sleep duration between self-report and actigraphy in both older men and women, yielding high false-negative and false-positive rates for self-report when compared with the more objective measure of actigraphy.

The frequent disagreement between self-reported and actigraphy-measured sleep duration in older men and women, whether in the direction of false negatives or false positives, has important clinical and research implications. False negatives represent a missed opportunity to intervene on modifiable risk factors and minimize adverse health outcomes. False positives, on the other hand, may lead to unnecessary or potentially harmful interventions (eg, hypnotic use to increase sleep time).[39] With respect to research, these results suggest that reliance on self-reported sleep duration may result in misclassification, biasing toward null results. However, it is also possible that the perception of short sleep is the more potent correlate of adverse outcomes, or that self-reported and actigraphy-measured sleep represent different, albeit equally important, constructs that predict distinct adverse outcomes. These concerns underscore the need to confirm self-reported sleep duration with objective measures when evaluating the effect of short sleep on adverse health outcomes. Additionally, whether misclassification of

Figure 1—Bland-Altman plots showing the agreement between objective (actigraphy) and self-reported measures of sleep duration in MrOS and SOF.



(A) MrOS, men. **(B)** SOF, women. Dotted lines represent upper and lower 95% limits of agreement. The unbroken red line represents mean differences.
MrOS = Osteoporotic Fractures in Men Sleep Study, OBJ = actigraphic sleep duration, SOF= Study of Osteoporotic Fractures, SUBJ = self-reported sleep duration.

short sleep by self-report leads to adverse health outcomes should be determined.

False-negative and false-positive rates were high in both sexes. Differences between the two cohorts should not be attributed solely to sex since substantial differences in clinical characteristics were present in the two cohorts (see **Table S1**). It is possible that rates may have been inflated in men due to systematic bias (ie, systematic overestimation of sleep duration by approximately 30 minutes in men by self-report compared to actigraphy). However, agreement among men remained poor, even after accounting for bias. False-positive rates were also high in both sexes. The opposing effect of certain characteristics (eg, obesity, daily napping, and SDB) with respect to false-negative vs false-positive designations suggests there may be a threshold effect, whereby persons with these conditions are aware of short sleep only when sleep duration is severely limited or when deeper stages of sleep are disrupted.

Several potential mechanisms may explain the disagreement between self-reported and objective measures of sleep duration. Previous studies among patients with CHF, SDB, and obesity have reported discrepancies between self-reported and objective sleep measures.[40–42] Among patients with SDB and heart failure, Mehra et al found high levels of disagreement between self-reported and objective measures of daytime sleepiness.[40] The authors noted an upregulation of inflammatory factors (tumor necrosis factor alpha and interleukin 6) in objective, but not self-reported, sleepiness, and postulated this upregulation may mediate the dissociation between self-reported and objective sleepiness.[40] High levels of tumor necrosis factor alpha and interleukin 6 were also documented in a study by Vgontzas et al among persons with SDB, with the highest levels occurring in obese patients.[41] In a subsequent study Vgontzas et al found that obesity alone (without SDB) was linked to underestimation of objective daytime sleepiness.[42] Similarly, our results from

Table 4—MrOS (men): adjusted odds of a false-negative designation (normal sleep duration by self-report but short sleep by actigraphy).

Characteristics[a]	Adjusted OR (95% CI)[b]
Age (per year)	1.01 (0.99, 1.03)
Non-White race	1.21 (0.80, 1.83)
Less than high school	1.01 (0.59, 1.73)
Widowed	1.67 (1.15, 2.42)
Obesity	2.03 (1.55, 2.66)
Diabetes	1.23 (0.89, 1.70)
Myocardial infarction	0.85 (0.62, 1.16)
CHF	2.01 (1.26, 3.19)
Stroke	0.42 (0.19, 0.91)
Physical inactivity (per SD increase)	0.79 (0.70, 0.89)
Antidepressant use	0.65 (0.41, 1.04)
Use of CNS-active medication	1.39 (0.96, 2.02)
Caffeine intake ≥ 190 mg/d	1.17 (0.94, 1.47)
Poor sleep quality	1.22 (0.80, 1.86)
Daytime sleepiness (ESS score > 10)	1.56 (1.12, 2.16)
Daily napping	2.34 (1.74, 3.15)
SDB	1.72 (1.35, 2.20)

Included men with normal sleep duration by self-report (n = 1,996). Participants having a false-negative designation (n = 492) were compared with those having a true-negative designation (normal sleep duration by self-report and actigraphy; n = 1,504). [a]See footnotes to Table 1 regarding sample sizes for clinical characteristics. [b]From a multivariable model, including all demographic and clinical characteristics listed in Table 1, that was derived using backward selection with $P \leq .20$ to remain in the model. The model maxRSQCv_PCT was 11.77, explaining 11% of total variance in the outcome. CHF = congestive heart failure, CI = confidence interval, CNS = central nervous system, ESS = Epworth Sleepiness Scale, MrOS = Osteoporotic Fractures in Men Sleep Study, OR = odds ratio, SD = standard deviation, SDB = sleep-disordered breathing.

Table 5—SOF (women): adjusted odds of a false-negative designation (normal sleep duration by self-report but short sleep by actigraphy).

Characteristics[a]	Adjusted OR (95% CI)[b]
Age (per year)	0.99 (0.94, 1.03)
African American	1.41 (0.89, 2.25)
Less than high school	1.03 (0.72, 1.49)
Obesity	1.62 (1.18, 2.22)
CHF	1.50 (0.92, 2.45)
Physical impairment	1.77 (1.33, 2.37)
Physical inactivity (per SD increase)	0.85 (0.73, 0.98)
Depression	0.56 (0.31, 0.99)
Anxiety	0.67 (0.36, 1.23)
Current smoking	1.67 (0.79, 3.54)
Daytime sleepiness (ESS score > 10)	1.93 (1.29, 2.90)
Daily napping	1.69 (1.16, 2.44)
RLS	1.80 (0.90, 3.63)

Included women with normal sleep duration by self-report (n = 1,626). Participants having a false-negative designation (n = 323) were compared with those having a true-negative designation (normal sleep duration by self-report and actigraphy; n = 1,303). [a]See footnotes to **Table 2** regarding sample sizes for clinical characteristics. [b]From a multivariable model, including all demographic and clinical characteristics listed in **Table 2**, that was derived using backward selection with $P \leq .20$ to remain in the model. The model maxRSQCv_PCT was 8.09, explaining 8% of total variance in the outcome. CHF = congestive heart failure, CI = confidence interval, ESS = Epworth Sleepiness Scale, OR = odds ratio, RLS = restless legs syndrome, SD = standard deviation, SOF = Study of Osteoporotic Fractures.

Table 6—MrOS (men): adjusted odds of a false-positive designation (short sleep by self-report but normal sleep duration by actigraphy).

Characteristics[a]	Adjusted OR (95% CI)[b]
Age (per year)	0.99 (0.96, 1.01)
Non-White race	0.74 (0.49, 1.12)
Less than high school	0.65 (0.37, 1.13)
Living alone	0.68 (0.46, 1.01)
Obesity	0.46 (0.32, 0.65)
Hypertension	1.20 (0.91, 1.58)
CHF	0.76 (0.46, 1.27)
Physical inactivity (per SD increase)	1.13 (0.99, 1.30)
Caffeine intake ≥ 190 mg/d	0.78 (0.59, 1.03)
Alcohol use (drinks per week)	0.97 (0.94, 1.01)
Poor sleep quality (PSQI item 9 score > 1)	1.39 (1.03, 1.86)
Daytime sleepiness (ESS score > 10)	0.75 (0.51, 1.10)
Daily napping	0.64 (0.45, 0.92)
SDB	0.68 (0.50, 0.92)

Included men with short sleep duration by self-report (n = 984). Participants having a false-positive designation (n = 510) were compared with those having a true-positive designation (short sleep duration by self-report and actigraphy; n = 474). [a]See footnotes to **Table 1** regarding sample sizes for clinical characteristics. [b]From a multivariable model, including all demographic and clinical characteristics listed in **Table 1**, that was derived using backward selection with P ≤ .20 to remain in the model. The model maxRSQCv_PCT was 9.34, explaining 9% of total variance in the outcome. CHF = congestive heart failure, CI = confidence interval, MrOS = Osteoporotic Fractures in Men Sleep Study, OR = odds ratio, PSQI = Pittsburgh Sleep Quality Index, SD = standard deviation, SDB = sleep-disordered breathing.

multivariable models in men support the possibility that obesity may be linked to discrepancies between self-reported and objective measures, independent of the effect of SDB. Vgontzas et al invoked central nervous system effects of inflammatory cytokines as potential mediators of objective daytime sleepiness in obese patients and also postulated that a circadian shift may be responsible for more fragmented sleep in obese participants during the night and more consolidated sleep (higher sleep efficiency) during the day when compared to healthy, nonobese controls.[42] While it is possible that persons with excessive daytime sleepiness or daily napping might overestimate overnight sleep duration as a result of daytime sleep, a circadian mechanism, similar to the shift postulated by Vgontzas et al among obese persons, may contribute to discrepancies between self-reported and objective sleep measures. Taken together, this body of work suggests disease-mediated inflammation or a circadian shift may contribute to the dissociation between self-reported and objective sleep measures. Interleukin 6 is of particular interest as levels of this cytokine are known to increase with obesity and advancing age, with evidence of sex-based differences in serum levels.[43,44] Other potential mechanisms include lifestyle factors (eg, greater flexibility in sleep–wake scheduling)[45,46] and neuropsychiatric mechanisms (eg, reduced symptom awareness).[7,47]

The strengths of the current study include analysis of two large and well-characterized cohorts with availability of validated sleep measures, a focus on vulnerable groups of older men and women at high risk for adverse outcomes, and examination of a broad range of aging-related factors in participants who were not selected for inclusion based on sleep-related criteria. We acknowledge, however, several limitations. First, this was a cross-sectional analysis, precluding evaluation of causal mechanisms or mediation by inflammatory factors. Second, actigraphy is an objective estimate rather than a direct measure of sleep and may estimate sleep poorly, especially in persons with poor sleep quality or highly sedentary status.[32,33,48] Nonetheless, actigraphic measures are highly correlated with PSG measures, especially total sleep duration, and actigraphy represents a more feasible methodology in older populations.[31] Third, PSG-confirmed SDB was not examined in the full SOF cohort and was not included in multivariable analyses. Fourth, the self-reported and actigraphy measures of sleep duration were not simultaneous and other differences in the methods (eg, the retrospective assessment of self-reported sleep over the past month vs prospective assessment of sleep by actigraphy over 5 nights and the requirement for participants to provide an estimate of sleep duration to the nearest integer) may have contributed to

Table 7—SOF (women): adjusted odds of a false-positive designation (short sleep by self-report but normal sleep duration by actigraphy).

Characteristics[a]	Adjusted OR (95% CI)[b]
Age (per year)	1.05 (1.01, 1.10)
African American	0.93 (0.62, 1.38)
Less than high school	1.22 (0.87, 1.71)
Obesity	0.61 (0.46, 0.82)
Myocardial infarction	1.20 (0.79, 1.82)
Physical impairment	0.65 (0.49, 0.85)
Daytime sleepiness (ESS score > 10)	0.46 (0.32, 0.67)
RLS	1.37 (0.77, 2.46)

Included women with short sleep duration by self-report (n = 1,229). Participants having a false-positive designation (n = 808) were compared with those having a true-positive designation (short sleep duration by self-report and actigraphy; n = 421). [a]See footnotes to **Table 2** regarding sample sizes for clinical characteristics. [b]From a multivariable model, including all demographic and clinical characteristics listed in **Table 2**, that was derived using backward selection with $P \leq .20$ to remain in the model. The model maxRSQCv_PCT was 6.42, explaining 6% of total variance in the outcome. CI = confidence interval, ESS = Epworth Sleepiness Scale, OR = odds ratio, RLS = restless legs syndrome, SOF = Study of Osteoporotic Fractures.

differences in the 2 measures. It is possible that direct comparisons between sleep diary and actigraphy measures of sleep duration may have better agreement. However, in clinical practice sleep duration is most often assessed through a retrospective estimate rather than through use of sleep diaries. In addition, it seems unlikely that variations in methodology alone could explain the large discrepancies between the two measures. Finally, a type 1 error may have occurred in 1 out of 20 comparisons in the multivariable models, which means that between 2 and 3 of the statistically significant results may have been false positives. Given these limitations, future work should confirm the associations demonstrated here. In addition, comparisons of self-reported, actigraphy-measured, and electroencephalography-measured sleep should examine which classification of short sleep is more strongly associated with adverse health outcomes using a longitudinal design that includes PSG measures and a broader array of mediating or moderating factors.

In conclusion, using data from 2 large cohorts of community-dwelling older persons, we have shown that there was minimal agreement between self-reported and actigraphic measures of sleep duration in older men and women, yielding high false-negative and false-positive rates for self-report when compared with objective measures of actigraphy. Our results highlight subgroups (eg, persons with obesity, daytime sleepiness, daily napping, or SDB) in whom an objective measure of sleep duration should be considered. These results have clinical implications, since false-negative designations may represent a missed opportunity to intervene on modifiable risk factors and minimize adverse health outcomes, while false-positive designations may lead to unnecessary or potentially harmful interventions.

ABBREVIATIONS

adjOR, adjusted odds ratio
CHF, congestive heart failure
ESS, Epworth Sleepiness Scale
MrOS, Osteoporotic Fractures in Men Sleep Study
OR, odds ratio
PSG, polysomnography
PSQI, Pittsburgh Sleep Quality Index
SDB, sleep-disordered breathing
SOF, Study of Osteoporotic Fractures

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