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# Sleep and functional capacity in adults: Cross-sectional associations among self-report and objective assessments

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## Abstract

**Objectives:** This study examined the relationship between self-reported and objectively measured sleep and functional capacity in adults.

**Design:** Cross-sectional.

**Participants:** Data were from the Midlife in the United States (MIDUS) study. The sample consisted of men and women ($n$ = 664) aged 25–83 who completed telephone interviews, questionnaires, and an overnight clinic stay.

**Measurements:** Sleep was assessed by self-report (Pittsburgh Sleep Quality Index (PSQI)) and by objective measures (sleep latency, duration, wake after sleep onset (WASO), and midpoint/midpoint variability) from 7 consecutive days of actigraphy. Functional capacity was assessed by self-report of limitations and measured gait speed, grip strength, and chair stands.

**Results:** In linear regression models adjusting for demographic and health factors, better self-reported sleep quality predicted fewer reported limitations, stronger grip, quicker gait, and faster chair stands (all $p < .01$). Greater WASO predicted more self-report limitations and slower gait speed ($p < .05$). Long (>8h) sleep duration and a more variable sleep schedule predicted lower grip strength ($p < .05$). Finally, after adjustment for objective sleep measures, PSQI remained a significant predictor of functional measures ($p < .05$) and explained a significant amount of additional variance (change in $R^2$: .01-.05).

**Conclusions:** The present results suggest that subjective and objective sleep measures capture distinct aspects of sleep that are independently related to functional capacity. The variance in functional measures explained by sleep variables, though small, was comparable to other risk factors for functional impairment (e.g., obesity), underscoring the importance of associations between sleep and optimal function in adults.

### Keywords

sleep; actigraphy; functional limitations; grip strength; gait speed; chair stands

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## Introduction

Average life expectancy has increased for most of the past 60 years, but the rate of increase has slowed over time and life expectancy decreased from 2014–2016.[1] Further, when adults live into old age, the years are not necessarily spent healthy. While changes in technology and the contexts in which people live have made it easier to cope with some conditions (e.g., physical immobility),[2] disability rates are increasing in new cohorts of older adults.[3] One analysis of trends from 2000 to 2008,[4] for example, concluded that those in the 65 – 74 and 75 – 84 age groups demonstrated stable limitations across time, while the 55 – 64 age group faced increases, and those aged 85 and older experienced decreases. While signs of functional impairment often culminate in old age, functional capacity is thought to be influenced by exposures and experiences throughout life.[5] Indeed, functional capacity is considered a key hallmark of healthy aging. Thus, a better understanding of diverse influences on functional capacity among adults across a broad age range is essential for improving quality of life. The current study examines the extent to which sleep is linked to functional status in a national sample of adult men and women.

Sleep problems affect an estimated 50 to 70 million Americans[6] and are particularly relevant for people aged 60 years or older, since at least 50% of older adults complain about difficulty sleeping and report sleep-related problems (e.g., disturbed or light sleep).[7] A growing number of studies suggest that poor sleep may be a risk factor for disability in later life. Adults with physician-diagnosed sleep disorders[8] and those with poorer sleep, as determined by either self-report[9,10] or actigrapy,[11,12] are significantly more likely to report functional limitations and/or disability than those with better quality sleep. Collectively, these studies support the possibility that poor sleep may contribute to declines in functional capacity, although the association between sleep and physical disabilities is likely to be bidirectional. Pain-related disability, for example, may impair sleep quality and quantity.[13,14]

The current study aims to address two issues that remain unclear from prior research. First, most studies to date are based on clinical or convenience samples and/or are limited to older adults, and so have limited generalizability. To address this issue we use data from the national Midlife in the United States (MIDUS)[15] study that include participants across a five decade range of middle and later life. Second, sleep and functional status have been assessed using both self-reported/subjective and objective measures, but rarely are the two types of measures combined into one set of analyses. Such analyses are potentially meaningful because comparisons of subjective (e.g., Pittsburgh Sleep Quality Index) and objective (multi-night actigraphy) sleep assessments typically yield modest correlations.[16,17] Similarly, there is generally moderate to strong agreement between self-assessed functional limitations and objective measures of functional capacity in community dwelling[18,19] and clinical samples,[20,21] although these findings are not always consistent.[22] These observations suggest that subjective and objective assessments of the same phenomenon (e.g., sleep) may have independent associations with functional capacity. The present study takes advantage of diverse assessments of sleep and functional capacity in the MIDUS study to examine the relationships among self-reported and objectively measured sleep and functional capacity. Specifically, we consider 1) the independent relationships among subjective and objective reports of both sleep and functional capacity and 2) the potential

overlap between subjective and objective sleep in predicting self-report and objective measures of function. We hypothesize that subjective and objective sleep assessments will have independent associations with self-reported and objectively-assessed functional capacity.

## Participants and Methods

### Sample

Data for the current study are from the Biomarker sub-samples from the second wave of the longitudinal MIDUS study (MIDUS 2; $n$ = 1,255) and the MIDUS Refresher study ($n$ = 863; combined sample = 2,118). MIDUS procedures and protocol have been described in detail elsewhere.[23,24] Briefly, MIDUS is a national longitudinal study of community-dwelling adults aged 25–75 at the first wave of data collection (1995–1996), with follow-up data collection in 2004–2006 (MIDUS 2) and 2013 (MIDUS 3). Data for a new Refresher cohort (age range 25–75) were collected 2011–2013.

In addition to telephone interviews and self-administered questionnaires completed by all MIDUS participants, Biomarker participants completed medical histories and clinical assessments during an overnight stay at one of three regional General Clinical Research Centers (GCRC). Biomarker participants at the University of Wisconsin-Madison GCRC ($n$ = 790) were also supplied with wrist-worn actigraphs for collection of sleep-wake activity for seven consecutive days. Comparisons of the Biomarker and full MIDUS samples have shown them to be comparable on all metrics, with the exception that the Biomarker sample had greater educational attainment.[24] A greater number of participants completed the questionnaire assessments than the objective sleep and function measures. Therefore, we limited the sample to those who had completed the objective assessments so that all models had a similar number of cases and comparable power. The analytical sample consisted of 664 participants, with some data missing for specific variables (samples for each model are indicated in Table 3). Collection of data for MIDUS and analysis of those data for the current study were approved by the Institutional Review Boards at the University of Wisconsin-Madison and Purdue University.

### Objective Physical Function

For conceptual clarity, we use “physical function” to refer to the objective assessments of grip strength, gait speed, and chair stands, and “functional limitations” to refer to self-reported health limitations. We use the term “functional capacity” as a broad term that encompasses both objective physical function and self-report functional limitations. Measures of functioning were obtained using validated physical exam protocol.[25] The functional assessments paralleled those in standard physical exams conducted by clinicians.[26,27]

*Grip strength* was measured using a dynamometer (kg/force). Participants gripped the meter in their right hand, which was supported on a surface, and squeezed as hard as they could. This was repeated and completed for the left hand, for a total of three trials for both the right

and left hands. In the present study, we used the average grip strength for the participants' dominant hand in all analyses.

*Gait speed* was assessed in a secluded hallway, where participants walked 25 feet to a designated mark, turned around, and walked back to the starting point. Participants were instructed to walk at their usual speed. A stopwatch was used to time each walk. The test was completed twice, and we used the average of the two tests for analyses.

*Chair stands* were completed using a chair pushed up against a wall. Participants first sat in the chair with their feet flat on the floor and arms folded across the chest. From that position, they stood up and sat back down 5 times in a row as quickly as possible. They remained standing after the fifth repetition. The time it took to complete 5 reps was recorded.

## Self-Report Functional Limitations

*Functional limitations* were assessed using self-administered questionnaire items from Jette & Cleary's Functional Status Questionnaire[28], which has had reliability coefficients of .64 to .82. In the current study, reliability was .94. Respondents indicated how much their health limited their ability to lift or carry groceries; bathe/dress self; climb one flight of stairs; climb several flights of stairs; bend, kneel, or stoop; walk more than one mile; walk several blocks; walk one block; and engage in moderate or vigorous physical activity. Response options ranged from 1 (not at all) to 4 (a lot). Responses were averaged to create an overall limitations score (range: 1–4).

## Objective Sleep

The Actiwatch®−64 was used to collect sleep actigraphy data. Data collection began at 7:00 am on the Tuesday following the clinic stay, or in the event of travel the first available Tuesday, and concluded the following Tuesday morning. The watch detected number of movements per epoch (30 second intervals). Using a sleep diary, participants recorded the time they went to bed and began trying to go to sleep and the time they woke the next day and did not return to sleep. Intervals indicating rest periods were specified for each day based on sleep diary data, and summary statistics for each participant's sleep were generated using the manufacturer's software. A particular epoch was scored as wake or sleep by comparing activity counts for the epoch in question with those immediately surrounding and using activity thresholds set by the manufacturer. Participants were required to have at least 4 nights of sleep data to be included in the analyses. Additionally, those who were marked as having an idiosyncratic sleep pattern (e.g., due to work schedule or illness; $n$ = 13) or whose data collection involved sleep outside of their usual time zone ($n$ = 14) were excluded from analyses

*Duration* of sleep was calculated as the time (in hours) elapsed between the start time and the end time of a given sleep interval. There is a well-documented U-shaped association between sleep duration and morbidity and mortality[29] where risk for adverse health outcomes is lowest for those sleeping approximately 7 hours a night on average and higher for those sleeping fewer than 6 or more than 8 hours a night.[30] For this reason, we created a set of dummy-coded variables indicating short duration (<6 hours), long duration (>8 hours), and average duration (6–8 hours), the latter being the reference group.

*Sleep onset latency* was the length of time in minutes until the onset of sleep after participants first attempted to sleep.

*Wake after sleep onset (WASO)* captured the amount of time in minutes that a participant spent awake after initially falling asleep. In the present sample, average latency ranged from .21 to 217.86; WASO ranged from 6.5 to 175.21. Sleep latency and WASO greater than 30 minutes are considered common cutoffs for insomnia.[31] For ease of interpretation we converted the average latency and WASO variables to 30-minute units. Thus, a value of 1 or greater for either of these variables suggests potential sleep problems.

*Sleep midpoint* was calculated as the midpoint between the sleep period start time and the end time; these were then averaged across the 7 days. To assess variability in sleep timing, we calculated the standard deviation in sleep midpoint across the 7 days, smaller values reflecting more consistent sleep schedules.

## Subjective Sleep

*The Pittsburgh Sleep Quality Index (PSQI)*,[32,33] developed by Buysse and colleagues, is a self-administered questionnaire used to assess participants' sleep quality over the past month. The PSQI includes 7 components (subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances range, use of sleeping medication, and daytime dysfunction) that are summed into a global score (range: 0–21). The global score was used for all analyses, higher scores indicating more sleep problems. The developers' initial evaluation[33] found an internal reliability of .83; in the current study, reliability was .73.

## Covariates

To control for potential confounds, age, sex, educational attainment, race, marital status, disease burden, and obesity were all included in the analyses as covariates. Age was assessed using a continuous variable. Respondents indicated their highest level of educational attainment using 12 categories ranging from "no school/some grade school" to "PhD, MD, JD, or other professional degree." Responses were then combined into three categories: high school degree or GED, some college, and college degree or more. As most (67%) participants identified as White, with 28% identifying as Black/African American, 1% as Native American or Alaska Native, 1% as Asian; <1% as Hispanic/Latino or mixed race, and 3% as other, we created a dichotomous variable to indicate race (1=persons of color). Dichotomous variables were also used for sex (1=female), marital status (1=married), and obesity (1=obese/body mass index[BMI]>30). We assessed disease burden using a multimorbidity weighted index.[34] Higher scores indicated greater burden. The Biomarker clinic stay followed the completion of telephone and questionnaire assessments, the elapsed time differing among participants. To account for variability in this time lag, we included a variable for time (in months) between assessments as a covariate in all models.

## Analytic Strategy

We initially examined bivariate correlations among all key study variables. Then, we confirmed linearity between predictors and outcomes and acceptable levels of

multicollinearity. Using a criterion of 3 standard deviations from the mean, we identified 1 outlier for grip strength, 10 outliers for chair stands, and 11 outliers for gait speed. The models produced similar results with these outliers included or excluded, so we included these values in the analyses. The functional limitations variable was slightly positively skewed, but because regression results were comparable with the raw variable and the log-transformed variable, we used the raw variable to maintain interpretability.

Predictor variables included the subjective and objective sleep measures: PSQI, WASO, sleep latency, sleep duration (short duration and long duration groups), mean sleep midpoint, and variability of sleep midpoint. Outcome variables included subjective and objective function measures: self-reported limitations, grip strength, gait speed, and chair stands. We entered one predictor into the regression with one outcome, until every combination of predictor and outcome had been accounted for. Thus, one model regressed PSQI on limitations; a separate model regressed PSQI on grip strength; a third model regressed PSQI on gait speed; and a different model regressed PSQI on chair stands. All models adjusted for the same covariates listed above.

In supplemental analyses we examined the strength of association between sleep measures and functional capacity measures when both objective and subjective sleep measures were included in the models. We ran a separate regression for each of the four functional outcomes and included sleep assessments that were significantly associated with the outcome of interest in the individual regression models. We conducted all analyses in Stata 16.

All analyses were conducted with unweighted data. While MIDUS is a nationally representative sample,[15] its primary strength lies with the scope of multi-disciplinary data collected and the concomitant ability to examine associations among a broad swath of social, psychological, and health measures. Furthermore, the current analysis used data from the Biomarker subsample of MIDUS, for which population-level weights are unavailable.

## Results

The total analytic sample included 664 participants (58.6% female; $M_{age}$ = 52.5). Table 1 lists participants' characteristics. As shown in Table 2, the three objective physical function measures were related to each other in the expected directions. Self-reported functional limitations also correlated with the objective function measures. All of the objective sleep measures were significantly correlated, except for sleep duration and mean midpoint. The PSQI was related to all objective sleep assessments.

### Individual Regression Models

We estimated separate regression models for each combination of the seven sleep predictors and four functional outcomes, with one predictor and one outcome in each regression to determine the independent associations. The PSQI global score was the only predictor that was significantly associated with all four functional outcomes. Wake after sleep onset (WASO) was associated with functional limitations ($b$ = .09, $p$ = .02) and gait speed ($b$ = .64, $p$ = .02). Standard deviation of sleep midpoint was significantly correlated with grip

strength ($b$= .36, $p$ = .03). All individual regression results are listed in Table 3. To aid interpretation, we centered and standardized the mean midpoint and standard deviation of midpoint variables.

### Supplemental Analyses

Finally, we determined whether subjective and objective sleep assessments were independently associated with the functional measures. We estimated models using sleep predictors that were significantly associated with the functional measures in the individual regression models. Model 1 included just the covariates; Model 2 added PSQI global scores; Model 3 included covariates and actigraphic sleep measures; Model 4 comprised the covariates, actigraphic sleep measures, and PSQI. The variables were entered in this order to first determine the variance explained by PSQI alone (Model 2), to determine the variance explained by the objective sleep measures (Model 3), and to determine whether PSQI scores independently predicted functional measures after accounting for objective sleep (Model 4).

As shown in Table 4 (Model 2), PSQI scores explained a significant amount of variance in functional limitations over that explained by the covariates (4.9% change in $R^2$, $p < .001$), and when PSQI scroes were added to the model that included objective sleep measures (Model 4), they were significantly associated with functional limitations ($b = .05$, $p < .001$) and explained a significant amount of additional variance (4.42% change in $R^2$, $p < .001$). We observed a similar trend with gait speed as the outcome (Table 5); PSQI scores significantly predicted gait speed ($b = .18$, $p = .004$; Model 2) and this effect was robust to the inclusion of WASO ($b = .15$, $p = .02$; Model 4). Results from models involving other functional measures were similar (data not shown).

## Discussion

In earlier work we found that subjective sleep complaints (chronic sleeping problems in the prior 12 months) were prospectively linked with larger increases in self-reported functional limitations and greater risk of incidence of new functional limitations over a 9–10 year follow-up period.[10] The central limitation of this earlier work was the subjective and self-report nature of the sleep and functional capacity measures, respectively. It is possible that subjective perceptions of poor health generally or general tendencies toward negative perceptions (e.g. neuroticism) may have colored participants' perceptions of the quality of their sleep and their functional capacity, although additional analyses in this earlier work suggested these factors did not affect the main findings. The current analyses, using both subjective/self-report and objective measures of both sleep and functional capacity, were designed to provide confirmation of this earlier work. We also addressed two of the existing gaps in the literature by incorporating multiple assessments of objective and subjective sleep and functional capacity and by using a national sample of community-dwelling middle-aged and older adults from MIDUS. The results supported our hypothesis that subjective and objective sleep assessments would have independent associations with self-reported and objective functional capacity. Notably, the PSQI was the strongest predictor for all functional outcomes and remained significant when sleep actigraphy measures were included in the models.

The inclusion of diverse subjective and objective assessments provided the opportunity to examine the extent of concordance or discordance among them. Correlations between objective measures of physical function (grip strength, gait speed, and chair stands) and self-reported functional limitations were small-to-moderate, results that are consistent with earlier studies indicating moderate to strong correlations between self-assessed functional limitations and objective measures of functional capacity in community[18,19] and clinical samples.[20] Of the functional objective measures, gait speed was most strongly related to self-reported functional limitations, suggesting that adults may base their judgements of functional limitations more on ambulatory speed than on strength. Correlations among actigraphic measures and PSQI scores were small-to-moderate in size, also consistent with prior literature.[16,17] Overall, then, the magnitude of agreement between subjective reports and objective assessments of the same phenomenon (sleep; functional capacity) tended to be moderate at best, in line with a range of prior studies; that the current results are based on data from a national sample of adults bolsters the existing literature.

The present results suggest further that subjective and objective sleep measures capture distinct aspects of sleep that are independently related to functional status. Of all the sleep assessments, PSQI global scores were the most robust predictors of functional capacity, possibly because the PSQI is multi-faceted, comprising subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. Each of the actigraphy measures, although used widely and validated in several populations, captures just one dimension of sleep (e.g., latency), and the variance in functional outcomes each is likely to explain is small. However, in models that included both objective and subjective measures of sleep, PSQI global scores remained significantly related to functional capacity above and beyond the variance already accounted for by the actigraphy measures. Moreover, although the incremental change in explained variance associated with the addition of PSQI scores was relatively small (.05 for functional limitations and .01 for gait speed), this magnitude is comparable to other established risk factors for functional impairment, including obesity in our sample (data not shown).

It is interesting to note that variability in sleep timing, but not typical sleep timing (midpoint), was significantly associated with at least one functional outcome (i.e., grip strength). Irregular sleep/wake patterns have been associated with delayed circadian rhythms.[35] Further, increased variability in sleep midpoint and sleep onset timing have been associated with hypertension[36] and higher prevalence and incidence of metabolic abnormalities,[37] respectively. These results suggest that regularity and routine in timing of sleep may be more important predictors of functional capacity and other health outcomes than timing of sleep *per se*.

Some limitations should be considered when interpreting the results of the present study. First, the analyses were cross-sectional, so the direction of influence is unclear. Indeed, poor sleep quality may result from functional limitations and associated chronic conditions, and a potential bidirectional association between functional capacity and sleep may exist.[13,14] Longitudinal examination of associations between subjective and objective sleep and functional capacity will be important for determining the directions of influence and

their magnitude. Additionally, objective sleep measures comprised actigraphy rather than polysomnography, the current gold standard for measuring sleep. Polysomnography and actigraphy correspond reasonably well,[38] but those with poor sleep quality tend to have the largest measurement error.[39] Actigraphy is also known to overestimate sleep and underestimate wake time,[38] in part because quiet inactivity can be confused with sleep, particularly in those with chronic conditions.[40] That said, concerns about misclassification of sleep were largely mitigated in the present study by the use of sleep diaries to establish the time that participants intended to start their sleep period. Moreover, actigraphy allows for the assessment of large numbers of participants in their everyday environments and over multiple nights, thus increasing ecological validity; this kind of study would not be feasible at the same scale using polysomnography.

### Conclusions

Despite these limitations, there are many strengths of the present study. The analyses comprise a large, national sample with significant gender, age, and racial diversity. We included multiple objective measures of both sleep and functional capacity, providing a more comprehensive assessment of these constructs. Overall, results suggest that subjective and objective measures of sleep capture different aspects of sleep quality that are both meaningfully associated with functional capacity in adults.

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**Table 1**

Participant characteristics (n=664)

| | Mean (SD) | Range | % |
|---|---|---|---|
| Age (years) | 52.54 (12.12) | 25 – 83 | |
| Sex (female) | | | 58.58 |
| *Education* | | | |
| High school/GED or less | | | 29.07 |
| Some College | | | 30.12 |
| College or more | | | 40.81 |
| Persons of color | | | 32.68 |
| Married | | | 59.04 |
| Obese (BMI > 30) | | | 47.89 |
| Disease burden | 2.79 (3.77) | −.07 – 28.76 | |
| *Average sleep duration* | | | |
| <6 hours | | | 40.66 |
| 6 – 8 hours | | | 55.87 |
| >8 hours | | | 3.46 |

*Note*. GED = General Education Diploma. BMI = body mass index.

**Table 2**

Pairwise correlations

| | Grip strength (kg/ force) | Gait speed (secs.) | Chair stands (secs.) | Mobility Limitations | PSQI | WASO (mins.) | Latency (mins.) | Duration (hrs.) | Mean | SD (hrs.) |
|---|---|---|---|---|---|---|---|---|---|---|
| Gait speed | −.22*** | | | | | | | | | |
| Chair stands | −.23*** | .56*** | | | | | | | | |
| Mobility Limitations | −.24*** | .47*** | .31*** | | | | | | | |
| PSQI | −.16*** | .28*** | .16*** | .39*** | | | | | | |
| WASO | −.04 | .23*** | .16*** | .23*** | .28*** | | | | | |
| Latency | −.04 | .18*** | .16*** | .22*** | .28*** | .35*** | | | | |
| Sleep Duration | −.08* | −.10* | −.07 | −.07 | −.18*** | −.13*** | −.33*** | | | |
| Sleep Midpoint | | | | | | | | | | |
| Mean | −.09* | .06 | .05 | .08* | .18*** | .09* | .17*** | .02 | | |
| SD | .03 | .01 | .00 | −.01 | .10* | .11** | .15*** | −.21*** | .23*** | |
| Mean | 33.12 | 16.38 | 10.32 | 1.67 | 6.25 | 47.89 | 31.10 | 6.19 | 2:58 AM | .88 |
| Range | 2.67 – 80.33 | 7 – 57.5 | 4 – 30 | 1 – 4 | 1 – 19 | 6.5 – 175.21 | .21 – 217.86 | 2.51 – 10.27 | 11:40 PM – 10:42 AM | .09 – 33.65 |
| SD | 12.47 | 5.00 | 4.57 | .78 | 3.64 | 24.75 | 30.88 | 1.12 | 1.58 hours | 1.43 |

*Note*. PSQI = Pittsburgh Sleep Quality Index; WASO = wake after sleep onset. SD = standard deviation.

*** p < .001

** p< .01;

* p<.05.

## Table 3

Regression results examining one predictor and one outcome independently

| Predictor | Outcome | Coefficient | 95% Confidence Interval |
|---|---|---|---|
| PSQI | ADLs | .05*** | [.03, .07] |
| PSQI | Grip strength | −.24* | [−.46, −.02] |
| PSQI | Gait speed | .18** | [.05, .30] |
| PSQI | Chair stands | .11* | [.00, .23] |
| WASO | ADLs | .09* | [.01, .16] |
| WASO | Grip strength | −.43 | [−1.31, .45] |
| WASO | Gait speed | .64* | [.09, 1.19] |
| WASO | Chair stands | .48 | [−.03, 1.00] |
| Latency | ADLs | .03 | [−.03, .10] |
| Latency | Grip strength | −.57 | [−1.34, .20] |
| Latency | Gait speed | .15 | [−.21, .51] |
| Latency | Chair stands | .27 | [−.15, .69] |
| Short duration (<6 hrs.) | ADLs | −.04 | [−.15, .06] |
| Long duration (>8 hrs.) | ADLs | .10 | [−.18, .38] |
| Short duration (<6 hrs.) | Grip strength | −.21 | [−1.71, 1.30] |
| Long duration (>8 hrs.) | Grip strength | −3.83 | [−8.00, .33] |
| Short duration (<6 hrs.) | Gait speed | −.16 | [−.91, .59] |
| Long duration (>8 hrs.) | Gait speed | −.65 | [−2.14, .85] |
| Short duration (<6 hrs.) | Chair stands | .23 | [−.48, .95] |
| Long duration (>8 hrs.) | Chair stands | −.28 | [−1.53, .97] |
| Mean MP | ADLs | .03 | [−.04, .10] |
| Mean MP | Grip strength | −.56 | [−1.27, .15] |
| Mean MP | Gait speed | .09 | [−.25, .43] |
| Mean MP | Chair stands | .13 | [−.28, .53] |
| SD MP | ADLs | −.03 | [−.05, .00] |
| SD MP | Grip strength | .36* | [.03, .68] |
| SD MP | Gait speed | .00 | [−.17, .18] |
| SD MP | Chair stands | −.06 | [−.26, .14] |

*Note*. All models control for gender, age, race, disease burden, marital status, obesity, education, and the time lag between questionnaire assessments and the clinic stay. ADLs = Activities of daily living (higher values indicate more limitations); PSQI = Pittsburgh Sleep Quality Index; WASO = wake after sleep onset; MP = midpoint; SD = standard deviation. For interpretability, WASO and latency were converted to 30-minute units, and mean MP and SD MP were centered and standardized.

*** p < .001

** p< .01

* p<.05.

**Table 4**

Regression models predicting ADLs using objective and subjective sleep measures that are independently significant (n = 593)

| | Model 1 | Model 2[a] | Model 3[b] | Model 4[c] |
|---|---|---|---|---|
| *Covariates* | | | | |
| Age | .01** | .01*** | .01** | .01*** |
| Female | .03 | .07 | .05 | .08 |
| Persons of color | .17** | .09 | .14* | .08 |
| Disease burden | .10*** | .08*** | .09*** | .08*** |
| Married | −.07 | −.04 | −.05 | −.04 |
| Obesity | .28*** | .32*** | .29*** | .32*** |
| Education | −.13** | −.10** | −.12*** | −.10** |
| Time lag (months) | −.00 | −.00 | −.00 | −.00 |
| *Objective sleep* | | | | |
| WASO | | | .09* | .04 |
| *Subjective sleep* | | | | |
| PSQI | | .05*** | | .05*** |
| $R^2$ | .3953 | .4454 | .4026 | .4465 |
| Change in $R^2$ | | .0490 | .0073 | .0442 |
| $F$ for (change in) $R^2$ | 37.72*** | 37.80*** | 5.44* | 32.88*** |

*Note*. WASO = wake after sleep onset. PSQI = Pittsburgh Sleep Quality Index. For interpretability, WASO was converted to 30-minute units.

[a]Model 2 $R^2$ values reflect the change from Model 1 to Model 2.

[b]Model 3 $R^2$ values reflect the change from Model 1 to Model 3.

[c]Model 4 $R^2$ values reflect the change from Model 3 to Model 4.

*** p < .001

** p< .01

* p<.05.

## Table 5

Regression models predicting gait speed using objective and subjective sleep measures that are independently significant (n = 587)

| | Model 1 | Model 2[a] | Model 3[b] | Model 4[c] |
|---|---|---|---|---|
| *Covariates* | | | | |
| Age | .09*** | .10*** | .09*** | .10*** |
| Female | .33 | .56 | .48 | .68 |
| Persons of color | 1.71*** | 1.48*** | 1.48*** | 1.30** |
| Disease burden | .52*** | .47*** | .50*** | .47*** |
| Married | −.49 | −.35 | −.35 | −.25 |
| Obesity | .48 | .65 | .51 | .67* |
| Education | −.59** | −.60** | −.52* | −.55* |
| Time lag (months) | .02 | .01 | .02 | .02 |
| *Objective sleep* | | | | |
| WASO | | | .64* | .64* |
| *Subjective sleep* | | | | |
| PSQI | | .18** | | .15* |
| $R^2$ | .3146 | .3416 | .3236 | .3495 |
| Change in $R^2$ | | .0136 | .0090 | .0088 |
| $F$ for (change in) $R^2$ | 20.60*** | 7.84** | 5.27* | 5.52* |

*Note*. WASO = wake after sleep onset. PSQI = Pittsburgh Sleep Quality Index. For interpretability, WASO was converted to 30-minute units.

[a]Model 2 $R^2$ values reflect the change from Model 1 to Model 2.

[b]Model 3 $R^2$ values reflect the change from Model 1 to Model 3.

[c]Model 4 $R^2$ values reflect the change from Model 3 to Model 4.

*** $p < .001$

** $p < .01$

* $p < .05$.