## Title

Accelerometer-assessed sleep and decline in physical function in older men.



## Journal

Sleep Health, 10(1)

## Authors

Holingue, Calliope
Owusu, Jocelynn
Tzuang, Marian
et al.

## Publication Date

2024-02-01

## DOI

10.1016/j.sleh.2023.11.004

Peer reviewed

HHS Public Access

Author manuscript

*Sleep Health*. Author manuscript; available in PMC 2025 February 01.

Published in final edited form as:

*Sleep Health*. 2024 February ; 10(1): 129–136. doi:10.1016/j.sleh.2023.11.004.

# Accelerometer-Assessed Sleep and Decline in Physical Function in Older Men

**Calliope Holingue, PhD**[1], **Jocelynn T. Owusu, PhD**[1], **Marian Tzuang, PhD**[1], **Casandra C. Nyhuis, MHS**[1], **Kristine Yaffe, MD**[2,3], **Katie L. Stone, PhD**[4,5], **George W. Rebok, PhD**[1,6,7], **Sonia Ancoli-Israel, PhD**[8], **Adam P. Spira, PhD**[1,6,7]

[1.]Department of Mental Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA

[2.]Departments of Psychiatry, Neurology, Epidemiology and Biostatistics, University of California, San Francisco, CA, USA

[3.]San Francisco VA Medical Center, San Francisco, CA, USA

[4.]California Pacific Medical Center Research Institute, San Francisco, CA, USA

[5.]Department of Epidemiology and Biostatistics, University of California, San Francisco, CA, USA

[6.]Department of Psychiatry and Behavioral Sciences, Johns Hopkins School of Medicine, Baltimore, MD, USA

[7.]Johns Hopkins Center on Aging and Health, Baltimore, MD, USA

[8.]Department of Psychiatry, University of California San Diego, San Diego, CA, USA

## Abstract

**Study Objectives:** Assess the prospective association of actigraphically measured sleep with self-report and objective measures of physical function among community-dwelling older men.

**Corresponding author:** Calliope Holingue; Hampton House, Office 850, 624 N Broadway, Baltimore, MD, 21205; choling1@jhu.edu.

CRediT author statement

**Calliope Holingue:** conceptualization, software, formal analysis, writing – original draft, writing – review and editing
**Jocelynn T Owusu:** conceptualization, software, formal analysis, writing – original draft, writing – review and editing
**Marian Tzuang:** conceptualization, software, formal analysis, writing – original draft, writing – review and editing
**Casandra C. Nyhuis:** writing – original draft, writing – review and editing
**Kristine Yaffe:** conceptualization, writing – original draft, writing – review and editing, supervision
**Katie L. Stone:** conceptualization, writing – original draft, writing – review and editing, supervision
**George W Rebok:** conceptualization, writing – original draft, writing – review and editing, supervision
**Sonia Ancoli-Israel:** conceptualization, writing – original draft, writing – review and editing, supervision
**Adam P Spira:** conceptualization, writing – original draft, writing – review and editing, supervision

**Conflicts of Interest:** Sonia Ancoli-Israel is a consultant for Eisai, Merck, and Idorsia. Adam Spira received payment for serving as a consultant for Merck, received honoraria from Springer Nature Switzerland AG for guest editing special issues of *Current Sleep Medicine Reports*, and is a paid consultant to Sequoia Neurovitality. The authors declare no other financial or non-financial conflicts of interest.

**Methods:** Participants were (n=1,496) men aged ≥65 years from the Osteoporotic Fractures in Men Study (MrOS) and ancillary Sleep Study who were followed up at four years for physical function outcomes. Sleep predictors included baseline total sleep time (TST; <6, 6–8 hours (reference), >8 hours), sleep efficiency (SE; <80% or ≥80% (reference)), wake after sleep onset (WASO; <90 (reference) or ≥90 minutes), and sleep onset latency (SOL; <30 (reference) or ≥30 minutes), measured by wrist actigraphy. Outcomes included self-reported difficulties in mobility and instrumental activities of daily living (IADLs), and objective measures of physical performance (time to complete chair stands, gait speed, grip strength, best narrow walk pace). Multivariable regression models estimated associations between the sleep predictors and change in physical function at follow-up, adjusting for demographic and health-related variables.

**Results:** Participants with short average baseline TST (<6 hours) had significantly greater slowing in their walking speed from baseline to follow-up. Participants with long baseline SOL (≥30 minutes) had significant increases in mobility difficulties and time to complete chair stands. SE and WASO were not significantly associated with any outcomes. No sleep predictors were associated with change in IADLs.

**Conclusions:** These findings add to the body of evidence showing links between poor sleep and subsequent declines in physical function. Further experimental research is needed to understand the mechanisms at play.

### Keywords

sleep; actigraphy; function; mobility; IADLs; men

## Introduction

An estimated 40% of the US adult population aged 65 and older experience disability or have limitations in their activities of daily living. Decline in physical functioning in this population is a risk factor for falls, deterioration in health, and mortality.[2–4] Given the aging of the population globally,[5] it is becoming increasingly important to identify modifiable risk factors for decline in physical performance, which may lead to preventative strategies.[6]

A growing literature has tied poor sleep to greater disability and poorer physical function. Studies that have measured sleep using actigraphy have shown that short total sleep time is associated with mobility difficulties and preclinical physical disability.[7] Lower sleep efficiency has been linked to a decline in activities of daily living, and increased wake after sleep onset has been linked to poorer physical function.[9] However, these actigraphy-based studies have had small sample sizes[7,8] or have been cross-sectional in design.[7,9]

Larger, prospective studies examining the link between sleep and functional decline in older adults have been carried out, but mostly using self-report sleep measures.[10–13] These studies have shown that older men reporting poorer sleep quality had a higher risk of an increase in difficulties with activities of daily living over time,[13] that chronic sleep complaints were associated with physical symptoms such as pain, angina and difficulty breathing, and functional problems,[10,11] and that both self-reported extended time-in-bed and long total sleep time were associated with greater decline in physical function.[12] The potential

for discordance between self-report and accelerometer-assessed sleep measures is well established, particularly for individuals with poor self-reported sleep quality.[14–16] Therefore, inferences about the links between self-report poor sleep and functional decline may not necessarily apply to accelerometer-assessed sleep. In the present study, we investigated the prospective association of poorer accelerometer-assessed measured sleep with difficulties in mobility and instrumental activities of daily living (IADL) and decline in objective measures of physical performance in a large sample of community-dwelling older men.

## Methods

### Participants

The Osteoporotic Fractures in Men Study (MrOS) has previously been described(Blank et al., 2005; Orwoll et al., 2005). In brief, 5,994 community-dwelling older men age 65 years or older were enrolled at 6 clinical centers across the United States between 2000 and 2002. Eligibility criteria included the ability to walk without assistance and no history of bilateral hip replacement. Between December 2003 and March 2005, participants (n=3,135) were recruited for sleep assessment from this parent cohort into the ancillary MrOS Sleep Study.[18] Participants were followed longitudinally. Data in this paper are from the initial sleep visit—termed “baseline” in this paper —and the Visit 3 “follow-up”, which occurred between March 2007 and March 2009. In the present analysis, participants missing all actigraphy variables were removed from the analysis (n=80). Individuals with the maximum number of IADL (3 possible) or mobility difficulties (2 possible) at baseline were also excluded (n=169). We also excluded individuals missing both IADL and mobility outcomes (n=468) and participants missing all performance-based outcomes (n=916). Lastly, 6 participants in assisted living were removed from the analysis. No other exclusions were made. The final analytic sample consisted of 1,496 men (Figure 1), all of whom were community-dwelling. Within this sample, the time between baseline and follow-up was 3.4 years on average (median 3.0, range 2–5, SD 0.61).

Informed consent was obtained from each participant. The study was approved by the local institutional review board at each site.

### Measures

**Wrist actigraphy—**Participants wore a wrist actigraph (SleepWatch-O, Ambulatory Monitoring, Inc., Ardsley, NY) continuously at baseline (Dec 2003-March 2005). Participants were asked to wear the device continuously on the nondominant wrist for five consecutive 24-hour periods. The actigraphy data were analyzed using ActionW-2 software. Details of the protocol and actigraphy scoring algorithm have been previously described.[18–20] Participants completed sleep diaries for the time period in which they wore the actigraph, recording the time into and out of bed as well as when the actigraph was removed. This information was used to edit the actigraphy data to set accurate in-bed intervals during which the participant was attempting to sleep. The actigraph and sleep diary data were used to estimate several sleep parameters. In our analytic sample of 1496 people, 8 people (<1%) did not complete a sleep diary. Of the ones that did complete a sleep diary, 81% are noted as being completely accurate across all nights of collected data. On average, the sleep diaries

matched the actigraphy data within 30 minutes for 90% of men for “lights out” and 93% men for the time they got out of bed. There were no individuals with exactly 100% sleep efficiency in our analytic sample. All participants had at least one usable night of data. In the dataset that is disseminated to researchers for use, there were 108 men who had at least one night dropped from the analysis because they removed the watch for over 2 hours. Within our analytic sample, 97% of participants did not need to have any nights dropped from the analysis, though about 3% of the sample had between 1–4 nights excluded. Additional details about the wrist actigraphy can be found in the publication by Dam and colleagues.[9]

We studied the following, which were averaged over the nights of actigraphy: (1) total sleep time (TST; hours per nights spent sleeping in bed after “lights off”); (2) sleep efficiency (SE; percentage of time in bed spent sleeping after “lights off”); wake after sleep onset (WASO; minutes spent awake after the initial sleep onset of at least 20 minutes); and (4) sleep latency (SOL; the time elapsed between “lights off” and the onset of sleep.

We analyzed all sleep variables as categorical variables. TST was categorized as <6 hours, 6–8 hours (reference group), and >8 hours of sleep per night. Participants were categorized as having ≥80% SE (reference group) or <80% SE, and <90 or ≥90 minutes WASO. Lastly, SOL was dichotomized as <30 minutes (reference group) or ≥30 minutes a night. These cutoffs were chosen based on prior work in the MrOS cohort.[9]

**Performance-based measures of physical function—**Participants completed four performance-based measures at both baseline and follow-up: time to complete 5 chair stands, gait speed from a 6-meter walk, average grip strength, and the best narrow walk pace. Chair stand time (seconds) was measured by taking the sum of time to complete five chair stands, in which the participant was asked to rise from a chair without the use of their arms. Gait speed (meters/second) was measured using a standard 6-meter walking course, on which the participants completed two trials at their normal pace. Grip strength (kg) was measured by taking the average of four grip strength trials (two per hand) using a hand dynamometer. A narrow walking course (20 cm path over 6 meters) was used to test participant balance. A successful trial was one in which the participant did not step outside the 20 cm path or rely on staff or the wall for support. Up to two deviations were allowed per successful trial. Participants were given three attempts to complete two trials. The best (i.e., fastest) pace to complete a trial was used in this analysis. Further details on these tests can be found elsewhere.[9]

**Self-reported measures of mobility and instrumental activities of daily living —**Participants also were asked about difficulty with mobility and IADLs at baseline and follow-up. The two outcomes of interest in this analysis were any increase in mobility difficulties and IADL difficulties between the two timepoints. Mobility difficulties were assessed by asking whether the participants currently had any difficulty (yes/no): (1) walking 2 or 3 blocks outside on level ground; or (2) climbing up 10 steps without resting. Difficulties in IADLs were assessed by asking whether the participant had any difficulty (yes/no): (1) preparing their own meals; (2) doing heavy housework (e.g., scrubbing floors); or (3) doing their own shopping for groceries or clothes.[18,21,22] We treated these outcomes

as binary variables representing whether or not a participant experienced an increase in the number of mobility or IADL difficulties from baseline to follow-up.

**Other Measurements—**At baseline, participants completed questionnaires that asked about demographics, medical history, and other health-related variables. Participants brought all current prescription medication (any use in past 30 days) to their clinic visit. The Iowa Drug information Service drug vocabulary (College Pharmacy, University of Iowa, Iowa City, IA, USA) was used to classify medications, including benzodiazepines and antidepressants.[23] Health variables included history of smoking (never, past, current), depressive symptoms, benzodiazepine use, obesity, count of chronic health conditions, cognitive function, and antidepressant use. Height (cm) was measured using a wall-mounted Harpenden stadiometer. Bodyweight (kg) was measured using an electronic scale or calibrate balance beam. BMI ($kg/m^2$) was calculated based on height and weight; obesity was defined as a BMI of 30 $kg/m^2$ or greater. Depressive symptoms were measured at baseline using the Short Form (15 item) Geriatric Depression Scale (GDS), with higher scores corresponding to greater depressive symptomatology.[25,26] Cognitive function was assessed by trained staff using the Modified Mini-Mental State Examination (3MS). Scores on the 3MS range from 0–100 with higher scores reflecting higher cognitive function. Lastly, we calculated a count of prior diagnoses of common chronic illnesses (i.e., stroke or transient ischemic attack, diabetes, Parkinson's disease, chronic obstructive pulmonary disease, hypertension, coronary heart disease).

### Statistical Analysis

Logistic and linear regression models were performed to estimate the association between each of the sleep predictors (TST, SE, SOL, WASO) and each of the physical function outcomes. Logistic regression was used for the mobility and IADL difficulties models. Linear regression was used for the continuous change in performance-based outcomes. We fit unadjusted and multivariable models adjusted for age, race, education, smoking, depressive symptoms, obesity, count of chronic health conditions, 3MS score, benzodiazepine use, antidepressant use, and the baseline measure of the outcome (e.g., model estimating change in gait speed from baseline to follow-up adjusted for baseline gait speed). Due to sparseness across racial/ethnic categories, race was dichotomized as White versus non-White (Black/African-American, Asian, Hispanic, or other race). Associations with a p-value $<0.05$ were considered statistically significant. All analyses were performed in R Version 4.2.3 (2023–03-15) using the RStudio platform (Version 2023.06.1+524).[29,30]

## Results

### Characteristics of study population

The mean age at baseline was 74.55 (SD 4.52) (Table 1). Most participants were White (91%) and had higher than a high school education (81%). Most participants (92%) wore the actigraph for at least 5 nights (mean 5.1, median 5.0, SD 0.76, Range 1–11 nights). Only 0.2% of participants (3 individuals) in our analytic sample wore the device for only 1 night. At baseline, mean TST was 6.49 hours (SD 1.15), with 65% of participants sleeping 6–8 hours, 28% sleeping <6 hours, and 7% sleeping >8 hours on average. Mean SE was

84.13% (SD 9.07%) and 25% of the sample had SE <80%. Mean WASO was 70.81 minutes (SD 37.48) with 26% of the sample having WASO ≥90 minutes. The mean SOL was 29.91 minutes (SD 29.61) and 30% had a SOL ≥30 minutes.

At baseline, 95% had no IADL difficulties, 4% had 1 difficulty, and <1% had 2 difficulties. At follow-up, 93% had no IADL difficulties, 6% had 1 difficulty, 1% had 2 difficulties, and <1% had 3 difficulties. Similarly, 94% of participants had no mobility difficulties at baseline and 6% had 1 difficulty. At follow-up, 91% had no mobility difficulties, 7% had 1 mobility difficulty, and 2% had 2 difficulties. Most individuals (93%) did not have an increase in mobility difficulties from baseline (Mean 0.06 (SD 0.24)) to follow-up (Mean 0.10 (SD 0.35)). Similarly, most individuals (94%) did not have an increase in IADL difficulties from baseline (Mean 0.05 (SD 0.24)) to follow-up (Mean 0.09 (SD 0.34)). The mean, standard deviation, median, and range of the performance-based outcome measures for baseline, follow-up, and the change between the two visits are shown in Table 2.

## Association between sleep predictors and physical function

**Self-reported IADL and mobility difficulty—**Participants with long SOL (≥30min), relative to those with SOL <30 min, had significantly greater odds of an increase in mobility difficulties in both unadjusted (OR=2.06 [95% CI 1.36, 3.10] p<0.001) and adjusted models (OR=1.76 [95% CI 1.14, 2.70] p=0.01) (Table 3). Participants with long WASO (≥ 90 minutes), relative to short WASO (<90 minutes) also had significantly greater odds of an increase in mobility difficulties in the unadjusted model (OR=1.61 [95% CI 1.04, 2.46] p=0.03) but not the adjusted model (OR=1.36 [95% CI 0.85, 2.12] p=0.19) (Table 3). Neither TST nor SE was associated with mobility difficulty. There were no significant associations between any of the sleep predictors and an increase in IADL difficulties in either unadjusted or adjusted models (Table 4).

**Performance-based measures of physical function—**Compared to participants with <30 min of SOL, those with ≥30 min had a significantly greater change in chair stand time (i.e., a longer amount of time to complete chair stands at follow-up relative to baseline) in the unadjusted (β=0.41 [95% CI 0.11, 0.71] p=0.01), though the statistical significance was reduced in the adjusted model, i.e., no longer statistically significant(β=0.26 [95% CI −0.01, 0.52] p=0.06) (Table 5). Compared to participants with TST 6–8 hours, those with TST <6 hours had a significantly slower gait speed at follow-up compared to baseline in the unadjusted model (β=−0.03 [95% CI −0.05, −0.01] p=0.01) and the adjusted model (β=−0.03 [95% CI −0.04, −0.01] p=<0.001) (Table 6). Compared to participants with TST 6–8 hours, those with TST ≥8 hours did not have a significantly different change in gait speed at follow-up compared to baseline in either the unadjusted model (β=−0.01 [95% CI −0.04, 0.03] p=0.74) or the adjusted model (β=0.00 [95% CI −0.03, 0.03] p=0.96) (Table 6). Neither TST, SE, nor WASO was significantly associated with chair stand time change from baseline to follow-up (Table 5), and neither SE, WASO, nor SOL was significantly associated with gait speed change from baseline to follow-up (Table 6).

There were no significant associations between any sleep predictors and change in grip strength (Table 7) or change in the best narrow walk pace from baseline to follow-up in either unadjusted or adjusted models (Table 8).

## Discussion

The purpose of this study was to examine the association of poor sleep at baseline, measured by wrist actigraphy, with decline in physical function in a large sample of community-dwelling older men. We found that <6 hours of average TST time, relative to 6–8 hours, was significantly associated with slowing of walking speed during follow-up, and that participants with long SOL had a significant increase in mobility difficulties. SE and WASO were not significantly associated with any outcomes. Further, none of the three sleep predictors were significantly associated with an increase in IADL difficulties. Importantly, the significant findings in unadjusted models remained robust after adjusting for a host of potential confounders.

Much of the prior literature has documented associations between poor sleep and increases in difficulties with activities of daily living, physical symptoms, and physical function have used self-report measures of sleep.[10–13,31–33] Studies using actigraphy-measured sleep have been considerably less common than those using subjective reports. In a small cross-sectional study of community-dwelling older adults, Lorenz et al. found that actigraphically measured short total sleep time was associated with mobility difficulties.[7] In a cross-sectional study also using data from the MrOS cohort, Dam et al. found that wake after sleep onset of ≥90 minutes and sleep efficiency <80% were associated with lower grip strength and slower walking speed.[9]

We are only aware of two prospective studies that have used actigraphy to assess the relationships between sleep and functional or physical decline over time. In a small, prospective study of 121 older adults residing in assisted living facilities, Martin et al. observed that actigraphy-measured sleep efficiency was associated with a decline in activities of daily living. In a study of 817 women in the Study of Osteoporotic Fractures (SOF), Spira et al. observed that short sleep duration, greater wake after sleep onset, and lower sleep efficiency were associated with declines in function or physical performance, including incident impairment in IADLs and declines in grip strength.[17] In contrast to these two papers, we did not find that sleep efficiency, sleep latency, or total sleep time, were associated with an increase in IADL difficulties from baseline to follow-up or changes in grip strength. This discrepancy may be due to the slightly longer follow-up times and older age in the SOF compared to MrOS studies (5 years vs. 4 years and 82.4 vs. 74.6 years, respectively). However, we did observe that short sleep time was associated with slower gait speed and long sleep onset latency was associated with an increase in mobility difficulties.

Several possible mechanisms could explain the observed associations between poorer sleep at baseline and declines in functioning and physical performance over time. For example, short and long sleep duration is a risk factor for medical morbidity, including obesity, hypertension, diabetes, and cardiovascular disease,[34–36] which in turn may lead to poorer physical performance and ability to function. However, we found that the associations

observed remained even after adjusting for obesity and the number of chronic health conditions. Poor sleep could also negatively impact mental health and cognitive status,[34,37–40] both of which have been linked to decreased physical function.[41,42] Our analyses did adjust for depressive symptoms, antidepressant use, benzodiazepines use, and 3MS scores, but residual confounding is possible, and other phenomena may be underlying this association. For example, poor sleep may also cause exhaustion and fatigue[43] which increases the likelihood of worsening physical function, in part because tired individuals may engage less in health-promoting behaviors.[44,45] Lastly, sleep disturbances, including subjective poor sleep quality, short and long sleep, and partial and total sleep deprivation have all been linked to higher levels of inflammation.[46–50] In turn, increased levels of inflammatory markers in older adults have been associated with declines in physical function, including gait speed, grip strength,[52] and incident mobility difficulties,[53] though some research has been conflicting. These are important mechanisms to explore in future studies.

The current study had a number of strengths. It builds upon the existing body of literature by using a prospective study design,[7,9] large sample size,[7,8] and measurement of sleep by wrist actigraphy.[10–13] To our knowledge, no existing investigation of sleep in older men has included all three of these components within the same study. Participant outcomes included both self-reported measures of physical function (mobility and IADLs) and objective, performance-based measures of physical function. Lastly, we were able to adjust for a number of potential confounders of the pathway between sleep and physical function. However, this study also had some limitations. First, we limited the sample of participants to individuals who had not yet reached the maximum number of mobility or IADL difficulties at baseline, in order to look at worsening difficulties in these domains, meaning the most impaired individuals were likely not included in this analysis. Further, the MrOS study by design is restricted to individuals who can walk without assistance and who have not had bilateral hip replacements, at baseline. Therefore, our findings do not necessarily generalize to individuals with more extreme impairment or difficulties in physical function at baseline. Next, while this study is prospective and we adjusted for a number of potential health-related variables, it is possible that a process associated with disability, such as a heightened inflammatory state, caused both poor sleep at baseline as well as the decline in physical function at follow-up. Finally, over 90% of the individuals were White, non-Hispanic. The link between poor sleep and incident functional decline has been previously explored among older African-American men, but that study did not use a device to assess sleep.[13] Future studies using a more racially and ethnically diverse sample are needed, especially given the profound racial inequities in health.[55] Future research could also integrate other measures of sleep, such as napping, mean measures of bedtime/waketime/sleep midpoint, and measures of sleep variability.

Together, these findings indicate that specific aspects of sleep, specifically short sleep, and long sleep latency, may be modifiable risk factors for the prevention of functional decline and disability among community-dwelling older men. Future studies are needed to identify whether this represents a causal, direct link, or whether other processes such as inflammation and fatigue are confounding or mediating this pathway. Regardless, this work is important as it provides a risk factor for decline in physical function and suggests that

older adults with poor sleep may need to be monitored more closely and perhaps provided supportive services to prevent declines in physical function.

## Acknowledgments

Data from the Osteoporotic Fractures in Men (MrOS) Study are publicly available on the MrOS Online website. For more information or to download data, please visit: https://mrosonline.ucsf.edu

### Funding

NIMH Psychiatric Epidemiology Training Program (5T32MH014592–39), NIA/NIH Health Research Training in Age-Related Cognitive Disorders (T32-AG027668), NIA (R01AG050507–02S1, R01AG050507, RF1AG050745, R01AG049872, U01AG052445)

The Osteoporotic Fractures in Men Study (MrOS) is supported by NIH funding. The following institutes provide support: NIA, NIAMS, NCATS, NHLBI (U01 AG027810, U01 AG042124, U01 AG042139, U01 AG042140, U01 AG042143, U01 AG042145, U01 AG042168, U01 AR066160, UL1 TR000128, R01 HL071194, R01 HL070848, R01 HL070847, R01 HL070842, R01 HL070841, R01 HL070837, R01 HL070838, R01 HL070839)

## References

1. Bureau USC. Mobility is Most Common Disability Among Older Americans, Census Bureau Reports. 2014. Release Number CB14–218. https://www.census.gov/newsroom/press-releases/2014/cb14-218.html
2. Leveille SG, Guralnik JM, Ferrucci L, Langlois JA. Aging successfully until death in old age: opportunities for increasing active life expectancy. Am J Epidemiol. Apr 1 1999;149(7):654–64. doi:10.1093/oxfordjournals.aje.a009866 [PubMed: 10192313]
3. Manton KG. A longitudinal study of functional change and mortality in the United States. J Gerontol. Sep 1988;43(5):S153–61. doi:10.1093/geronj/43.5.s153 [PubMed: 2971088]
4. Viccaro LJ, Perera S, Studenski SA. Is timed up and go better than gait speed in predicting health, function, and falls in older adults? J Am Geriatr Soc. May 2011;59(5):887–92. doi:10.1111/j.1532-5415.2011.03336.x [PubMed: 21410448]
5. Ortman JM, Velkoff VA, Hogan H. An aging nation: the older population in the United States. 2014. http://usd-apps.usd.edu/coglab/schieber/psyc423/pdf/AgingNation.pdf
6. Guralnik JM, Fried LP, Salive ME. Disability as a public health outcome in the aging population. Annu Rev Public Health. 1996;17:25–46. doi:10.1146/annurev.pu.17.050196.000325 [PubMed: 8724214]
7. Lorenz RA, Budhathoki CB, Kalra GK, Richards KC. The relationship between sleep and physical function in community-dwelling adults: a pilot study. Fam Community Health. Oct-Dec 2014;37(4):298–306. doi:10.1097/fch.0000000000000046 [PubMed: 25167070]
8. Martin JL, Fiorentino L, Jouldjian S, Josephson KR, Alessi CA. Sleep quality in residents of assisted living facilities: effect on quality of life, functional status, and depression. J Am Geriatr Soc. May 2010;58(5):829–36. doi:10.1111/j.1532-5415.2010.02815.x [PubMed: 20722819]
9. Dam TT, Ewing S, Ancoli-Israel S, Ensrud K, Redline S, Stone K. Association between sleep and physical function in older men: the osteoporotic fractures in men sleep study. J Am Geriatr Soc. Sep 2008;56(9):1665–73. doi:10.1111/j.1532-5415.2008.01846.x [PubMed: 18759758]
10. Friedman EM. Self-Reported Sleep Problems Prospectively Increase Risk of Disability: Findings from the Survey of Midlife Development in the United States. J Am Geriatr Soc. Nov 2016;64(11):2235–2241. doi:10.1111/jgs.14347 [PubMed: 27626617]
11. Grossman ES. Enduring sleep complaints predict health problems: a six-year follow-up of the survey of health and retirement in Europe. Aging Ment Health. Nov 2017;21(11):1155–1163. doi:10.1080/13607863.2016.1209735 [PubMed: 27484858]
12. Stenholm S, Kronholm E, Bandinelli S, Guralnik JM, Ferrucci L. Self-reported sleep duration and time in bed as predictors of physical function decline: results from the InCHIANTI study. Sleep. Nov 1 2011;34(11):1583–93. doi:10.5665/sleep.1402 [PubMed: 22043129]

13. Thorpe RJ Jr. Gamaldo AA, Salas RE, Gamaldo, Whitfield KE. Relationship between Physical Function and Sleep Quality in African Americans. J Clin Sleep Med. Oct 15 2016;12(10):1323–1329. doi:10.5664/jcsm.6180 [PubMed: 27448426]

14. Parsey CM, Schmitter-Edgecombe M, Belenky G. Sleep and everyday functioning in older adulthood. J Appl Gerontol. Feb 2015;34(1):48–72. doi:10.1177/0733464812458364 [PubMed: 25548088]

15. Van Den Berg JF, Van Rooij FJ, Vos H, et al. Disagreement between subjective and actigraphic measures of sleep duration in a population-based study of elderly persons. J Sleep Res. Sep 2008;17(3):295–302. doi:10.1111/j.1365-2869.2008.00638.x [PubMed: 18321246]

16. Blackwell T, Redline S, Ancoli-Israel S, et al. Comparison of sleep parameters from actigraphy and polysomnography in older women: the SOF study. Sleep. Feb 2008;31(2):283–91. doi:10.1093/sleep/31.2.283 [PubMed: 18274276]

17. Spira AP, Covinsky K, Rebok GW, et al. Poor sleep quality and functional decline in older women. J Am Geriatr Soc. Jun 2012;60(6):1092–8. doi:10.1111/j.1532-5415.2012.03968.x [PubMed: 22690985]

18. Blackwell T, Yaffe K, Ancoli-Israel S, et al. Association of sleep characteristics and cognition in older community-dwelling men: the MrOS sleep study. Sleep. Oct 1 2011;34(10):1347–56. doi:10.5665/sleep.1276 [PubMed: 21966066]

19. Blackwell T, Ancoli-Israel S, Gehrman PR, Schneider JL, Pedula KL, Stone KL. Actigraphy scoring reliability in the study of osteoporotic fractures. Sleep. Dec 2005;28(12):1599–605. doi:10.1093/sleep/28.12.1599 [PubMed: 16408420]

20. Jean-Louis G, Kripke DF, Mason WJ, Elliott JA, Youngstedt SD. Sleep estimation from wrist movement quantified by different actigraphic modalities. J Neurosci Methods. Feb 15 2001;105(2):185–91. doi:10.1016/s0165-0270(00)00364-2 [PubMed: 11275275]

21. Fitti JE, Kovar MG. The Supplement on Aging to the 1984 National Health Interview Survey. Vital Health Stat 1. Jun 1987;(21):1–115.

22. Pincus T, Summey JA, Soraci SA Jr., Wallston KA, Hummon NP Assessment of patient satisfaction in activities of daily living using a modified Stanford Health Assessment Questionnaire. Arthritis Rheum. Nov 1983;26(11):1346–53. doi:10.1002/art.1780261107 [PubMed: 6639693]

23. Pahor M, Chrischilles EA, Guralnik JM, Brown SL, Wallace RB, Carbonin P. Drug data coding and analysis in epidemiologic studies. Eur J Epidemiol. Aug 1994;10(4):405–11. doi:10.1007/bf01719664 [PubMed: 7843344]

24. Prevention CfDCa. Defining Adult Overweight and Obesity. Accessed 03/04/2021, 2021. https://www.cdc.gov/obesity/adult/defining.html

25. Almeida OP, Almeida SA. Short versions of the geriatric depression scale: a study of their validity for the diagnosis of a major depressive episode according to ICD-10 and DSM-IV. Int J Geriatr Psychiatry. Oct 1999;14(10):858–65. doi:10.1002/(sici)1099-1166(199910)14:10<858::aid-gps35>3.0.co;2-8 [PubMed: 10521885]

26. Sheikh JI, Yesavage JA. Geriatric Depression Scale (GDS): recent evidence and development of a shorter version. Clinical Gerontologist: The Journal of Aging and Mental Health. 1986;doi:10.1300/J018v05n01_09

27. Teng EL, Chui HC. The Modified Mini-Mental State (3MS) examination. J Clin Psychiatry. Aug 1987;48(8):314–8. [PubMed: 3611032]

28. Glymour MM, Weuve J, Berkman LF, Kawachi I, Robins JM. When is baseline adjustment useful in analyses of change? An example with education and cognitive change. Am J Epidemiol. Aug 1 2005;162(3):267–78. doi:10.1093/aje/kwi187 [PubMed: 15987729]

29. RStudio: Integrated Development for R. RStudio, inc. Version Version 1.3.1093. 2016. https://rstudio.com

30. R: A language and environment for statistical computing. 2022. https://www.r-project.org

31. Lee JE, Ju YJ, Park EC, Lee SY. Effect of poor sleep quality on subjective cognitive decline (SCD) or SCD-related functional difficulties: Results from 220,000 nationwide general populations without dementia. J Affect Disord. Jan 1 2020;260:32–37. doi:10.1016/j.jad.2019.08.082 [PubMed: 31493636]

32. Vincent BM, Johnson N, Tomkinson GR, McGrath R, Clark BC, Choi BJ. Sleeping time is associated with functional limitations in a national sample of older Americans. Aging Clin Exp Res. Jan 2021;33(1):175–182. doi:10.1007/s40520-020-01524-0 [PubMed: 32170709]
33. Wang TY, Wu Y, Wang T, Li Y, Zhang D. A prospective study on the association of sleep duration with grip strength among middle-aged and older Chinese. Exp Gerontol. Mar 2018;103:88–93. doi:10.1016/j.exger.2018.01.009 [PubMed: 29329970]
34. Ancoli-Israel S. Sleep and its disorders in aging populations. Sleep Med. Sep 2009;10 Suppl 1:S7–11. doi:10.1016/j.sleep.2009.07.004 [PubMed: 19647483]
35. Buxton OM, Marcelli E. Short and long sleep are positively associated with obesity, diabetes, hypertension, and cardiovascular disease among adults in the United States. Soc Sci Med. Sep 2010;71(5):1027–36. doi:10.1016/j.socscimed.2010.05.041 [PubMed: 20621406]
36. Itani O, Jike M, Watanabe N, Kaneita Y. Short sleep duration and health outcomes: a systematic review, meta-analysis, and meta-regression. Sleep Med. Apr 2017;32:246–256. doi:10.1016/j.sleep.2016.08.006 [PubMed: 27743803]
37. Blackwell T, Yaffe K, Ancoli-Israel S, et al. Poor sleep is associated with impaired cognitive function in older women: the study of osteoporotic fractures. J Gerontol A Biol Sci Med Sci. Apr 2006;61(4):405–10. doi:10.1093/gerona/61.4.405 [PubMed: 16611709]
38. Miyata S, Noda A, Iwamoto K, Kawano N, Okuda M, Ozaki N. Poor sleep quality impairs cognitive performance in older adults. J Sleep Res. Oct 2013;22(5):535–41. doi:10.1111/jsr.12054 [PubMed: 23560612]
39. Stone KL, Xiao Q. Impact of Poor Sleep on Physical and Mental Health in Older Women. Sleep Med Clin. Sep 2018;13(3):457–465. doi:10.1016/j.jsmc.2018.04.012 [PubMed: 30098759]
40. Yaffe K, Falvey CM, Hoang T. Connections between sleep and cognition in older adults. Lancet Neurol. Oct 2014;13(10):1017–28. doi:10.1016/s1474-4422(14)70172-3 [PubMed: 25231524]
41. Auyeung TW, Kwok T, Lee J, Leung PC, Leung J, Woo J. Functional decline in cognitive impairment--the relationship between physical and cognitive function. Neuroepidemiology. 2008;31(3):167–73. doi:10.1159/000154929 [PubMed: 18784415]
42. Gray M, Gills JL, Glenn JM, et al. Cognitive decline negatively impacts physical function. Exp Gerontol. Jan 2021;143:111164. doi:10.1016/j.exger.2020.111164
43. Alfini AJ, Schrack JA, Urbanek JK, et al. Associations of Actigraphic Sleep Parameters With Fatigability in Older Adults. J Gerontol A Biol Sci Med Sci. Sep 16 2020;75(9):e95–e102. doi:10.1093/gerona/glaa137 [PubMed: 32502253]
44. Stenholm S, Kronholm E, Sainio P, et al. Sleep-related factors and mobility in older men and women. J Gerontol A Biol Sci Med Sci. Jun 2010;65(6):649–57. doi:10.1093/gerona/glq017 [PubMed: 20159778]
45. Tremblay MS, Colley RC, Saunders TJ, Healy GN, Owen N. Physiological and health implications of a sedentary lifestyle. Appl Physiol Nutr Metab. Dec 2010;35(6):725–40. doi:10.1139/h10-079 [PubMed: 21164543]
46. Irwin MR. Sleep and inflammation in resilient aging. Interface Focus. Oct 6 2014;4(5):20140009. doi:10.1098/rsfs.2014.0009
47. Irwin MR, Olmstead R, Carroll JE. Sleep Disturbance, Sleep Duration, and Inflammation: A Systematic Review and Meta-Analysis of Cohort Studies and Experimental Sleep Deprivation. Biol Psychiatry. Jul 1 2016;80(1):40–52. doi:10.1016/j.biopsych.2015.05.014 [PubMed: 26140821]
48. Irwin MR, Vitiello MV. Implications of sleep disturbance and inflammation for Alzheimer's disease dementia. Lancet Neurol. Mar 2019;18(3):296–306. doi:10.1016/s1474-4422(18)30450-2 [PubMed: 30661858]
49. Stahl ST, Smagula SF, Rodakowski J, et al. Subjective Sleep Quality and Trajectories of Interleukin-6 in Older Adults. Am J Geriatr Psychiatry. Feb 2021;29(2):204–208. doi:10.1016/j.jagp.2020.06.019 [PubMed: 32680764]
50. Irwin MR, Wang M, Campomayor CO, Collado-Hidalgo A, Cole S. Sleep deprivation and activation of morning levels of cellular and genomic markers of inflammation. Arch Intern Med. Sep 18 2006;166(16):1756–62. doi:10.1001/archinte.166.16.1756 [PubMed: 16983055]

51. Verghese J, Holtzer R, Oh-Park M, Derby CA, Lipton RB, Wang C. Inflammatory markers and gait speed decline in older adults. J Gerontol A Biol Sci Med Sci. Oct 2011;66(10):1083–9. doi:10.1093/gerona/glr099 [PubMed: 21719612]

52. Cesari M, Penninx BW, Pahor M, et al. Inflammatory markers and physical performance in older persons: the InCHIANTI study. J Gerontol A Biol Sci Med Sci. Mar 2004;59(3):242–8. doi:10.1093/gerona/59.3.m242 [PubMed: 15031308]

53. Penninx BW, Kritchevsky SB, Newman AB, et al. Inflammatory markers and incident mobility limitation in the elderly. J Am Geriatr Soc. Jul 2004;52(7):1105–13. doi:10.1111/j.1532-5415.2004.52308.x [PubMed: 15209648]

54. Taaffe DR, Harris TB, Ferrucci L, Rowe J, Seeman TE. Cross-sectional and prospective relationships of interleukin-6 and C-reactive protein with physical performance in elderly persons: MacArthur studies of successful aging. J Gerontol A Biol Sci Med Sci. Dec 2000;55(12):M709–15. doi:10.1093/gerona/55.12.m709 [PubMed: 11129392]

55. Chen X, Wang R, Zee P, et al. Racial/Ethnic Differences in Sleep Disturbances: The Multi-Ethnic Study of Atherosclerosis (MESA). Sleep. Jun 1 2015;38(6):877–88. doi:10.5665/sleep.4732 [PubMed: 25409106]

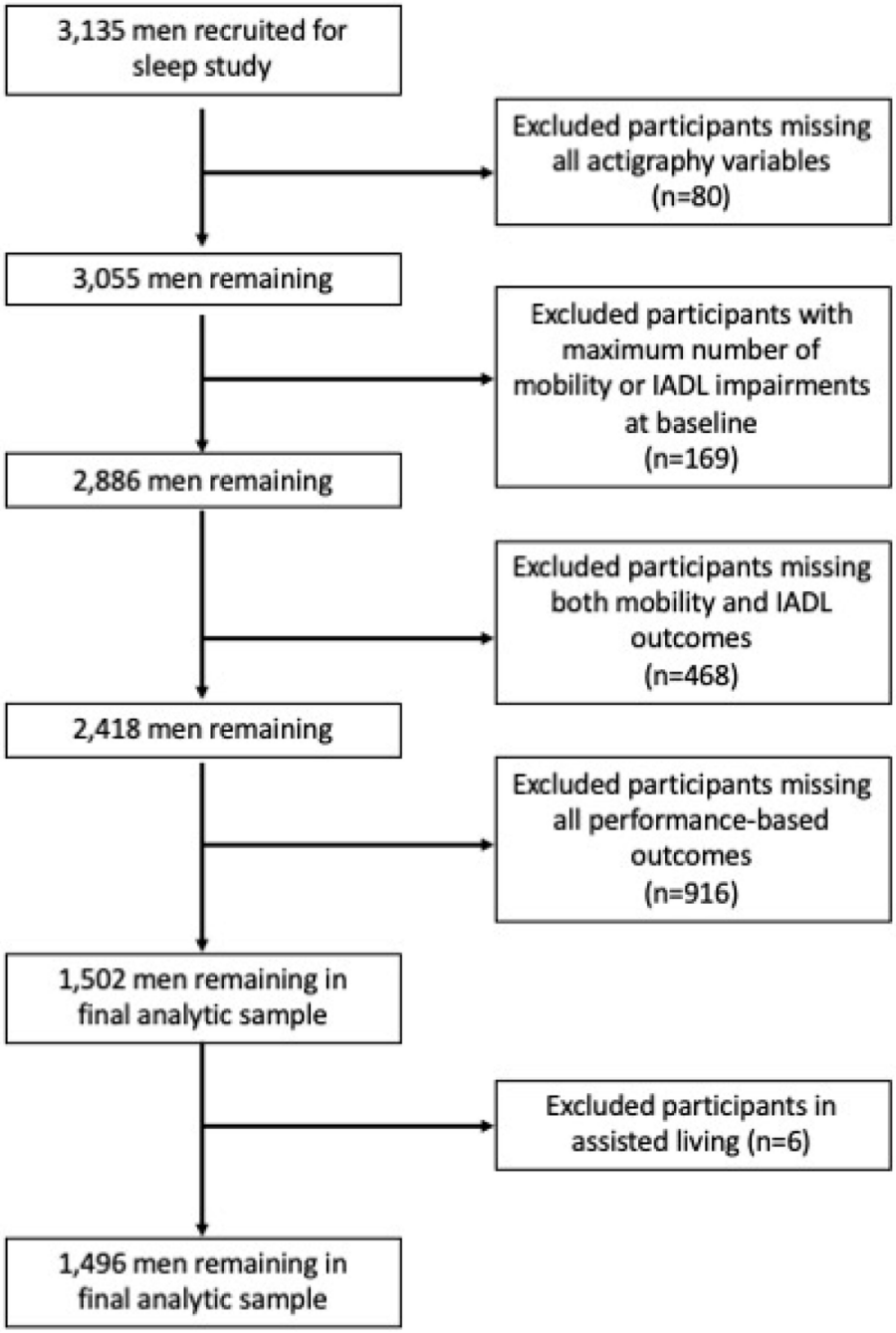


**Figure 1.**
shows the inclusions and exclusions that were made to the initial MrOS Visit 1 sleep study in order to arrive at the final analysis sample.

**Table 1.**

Participant Sleep Predictors and Covariates at Sleep Assessment (n=1,496)

| | Mean (±SD) or n (%) | Median | Range |
|---|---|---|---|
| Age (years) | 74.55 (±4.52) | 74.00 | (67.00–91.00) |
| Depressive symptoms | 1.39 (±1.87) | 1.00 | (0.00–13.00) |
| Cognitive function | 94.1 (±4.66) | 95.00 | (66.00–100.00) |
| Race | | | |
| White | 1364 (91.18) | --- | --- |
| Black or African-American | 44 (2.94) | --- | --- |
| Asian | 45 (3.01) | --- | --- |
| Hispanic | 28 (1.87) | --- | --- |
| Other | 15 (1.00) | --- | --- |
| Education | | | |
| High school education or below | 277 (18.52) | --- | --- |
| More than a high school education | 1219 (81.48) | --- | --- |
| Smoking | | | |
| Never | 618 (41.31) | --- | --- |
| Past | 846 (56.55) | --- | --- |
| Current | 32 (2.14) | --- | --- |
| Benzodiazepine use | 51 (3.41) | --- | --- |
| Antidepressant use | 85 (5.68) | --- | --- |
| BMI ≥30 | 258 (17.25) | --- | --- |
| Chronic health conditions (count) | | | |
| 0 | 721 (48.20) | --- | --- |
| 1 | 625 (41.78) | --- | --- |
| 2+ | 150 (10.03) | --- | --- |
| Total sleep time (hours) | 6.49 (±1.15) | 6.56 | (0.50–11.60) |
| 6–8 hours | 975 (65.17) | --- | --- |
| <6 hours | 420 (28.07) | --- | --- |
| >8 hours | 101 (6.75) | --- | --- |
| Sleep efficiency (%) | 84.13 (±9.07) | 86.20 | (30.93–99.27) |
| <80% | 376 (25.13) | --- | --- |
| Wake after sleep onset (minutes) | 70.81 (±37.48) | 63.54 | (4.80–273.6) |
| ≥90 minutes | 389 (26.00) | --- | --- |
| Sleep latency (minutes) | 28.91 (±29.61) | 20.54 | (3.80–303.75) |
| ≥30 minutes | 448 (29.95) | --- | --- |

Cognitive function was measured using the Modified Mini-Mental State Examination (3MS); scores range from 0–100 with higher scores indicating higher cognitive function. Depressive symptoms were assessed using the Short Form (15 item) Geriatric Depression Scale; higher scores indicate greater symptomatology. SD: standard deviation. BMI: body mass index.

**Table 2.**

Participant Outcomes Measures at Sleep (Baseline) and Follow-up Visit. (n=1,496)

| Timepoint | Mean (±SD) or n (%) | Median | Range |
|---|---|---|---|
| *Baseline Visit* | | | |
| Number IADL difficulties | 0.05 (±0.24) | 0 | (0 – 2) |
| Number mobility difficulties | 0.06 (±0.24) | 0 | (0 – 1) |
| Chair stand time | 10.82 (±2.92) | 10.51 | (0.14 – 25.16) |
| Gait speed | 1.22 (±0.21) | 1.21 | (0.35 – 2.03) |
| Grip strength | 40.00 (±7.70) | 40 | (14.00 - 64.50) |
| Best narrow walk pace | 1.18 (±0.25) | 1.17 | (0.38 – 2.09) |
| *Follow-up Visit* | | | |
| Number IADL difficulties | 0.09 (±0.34) | 0 | (0 – 3) |
| Number mobility difficulties | 0.10 (±0.35) | 0 | (0 – 2) |
| Chair stand time | 11.03 (±2.94) | 10.64 | (4.24 – 24.57) |
| Gait speed | 1.20 (±0.20) | 1.2 | (0.59 – 2.140) |
| Grip strength | 37.77 (±7.78) | 37.5 | (9.50 - 65.50) |
| Best narrow walk pace | 1.14 (±0.24) | 1.14 | (0.31 – 1.94) |
| Increase in mobility Difficulties | 99 (6.62%) | --- | --- |
| Increase in IADL Difficulties | 94 (6.28%) | --- | --- |
| *Change Between Visits* | | | |
| Change in chair stand time | 0.21 (±2.70) | 0.2 | (−11.64 – 15.79) |
| Change in gait speed | −0.02 (±0.18) | −0.02 | (−0.69 – 0.64) |
| Change in grip strength | −2.23 (4±.57) | −2 | (−19.00 - 19.50) |
| Change in best narrow walk pace | −0.04 (±0.23) | −0.03 | (−1.03 – 0.80) |

SD: standard deviation. IADL: instrumental activities of daily living.

**Table 3.**

Association between sleep parameters and odds of increase in mobility difficulties from baseline to follow-up*

| | Unadjusted Models | | | Adjusted Models | | |
|---|---|---|---|---|---|---|
| | Increase in number of mobility difficulties | | | Increase in number of mobility difficulties | | |
| | OR | 95% CI | P-value | OR | 95% CI | P-value |
| Total sleep time (ref: 6–8 hours) | --- | --- | --- | --- | --- | --- |
| Total sleep time <6 hours | 1.17 | (0.74 , 1.82) | 0.48 | 1.03 | (0.63 , 1.64) | 0.91 |
| Total sleep time >8 hours | 0.93 | (0.35 , 2.04) | 0.87 | 0.82 | (0.30 , 1.84) | 0.66 |
| Sleep efficiency (ref: ≥80% ) | --- | --- | --- | --- | --- | --- |
| Sleep efficiency <80% | 1.32 | (0.84 , 2.04) | 0.22 | 1.07 | (0.66 , 1.71) | 0.77 |
| Wake after sleep onset (ref: <90 minutes) | --- | --- | --- | --- | --- | --- |
| Wake after sleep onset ≥ 90 minutes | 1.61 | (1.04 , 2.46) | 0.03 | 1.36 | (0.85 , 2.12) | 0.19 |
| Sleep latency (ref: <30 min) | --- | --- | --- | --- | --- | --- |
| Sleep latency ≥30 min | 2.06 | (1.36 , 3.10) | <.001 | 1.76 | (1.14 , 2.70) | 0.01 |

Adjusted for age, race, education, smoking, depressive symptoms, obesity (BMI ≥30), count of chronic health conditions, modified Mini-Mental State Examination (3MS) score, benzodiazepine use, antidepressant use, and baseline measures of the outcome.

*Baseline refers to Sleep Visit; Follow-up refers to Visit 3. OR refers to Odds Ratio. 95% CI refers to 95% Confidence Interval.

**Table 4.**

Association between sleep parameters and odds of increase in IADL difficulties from baseline to follow-up*

| | Unadjusted Models | | | Adjusted Models | | |
|---|---|---|---|---|---|---|
| | Increase in number of IADL difficulties | | | Increase in number of IADL difficulties | | |
| | OR | 95% CI | P-value | OR | 95% CI | P-value |
| Total sleep time (ref: 6–8 hours) | --- | --- | --- | --- | --- | --- |
| Total sleep time <6 hours | 1.15 | (0.71 , 1.82) | 0.56 | 1.11 | (0.67 , 1.81) | 0.68 |
| Total sleep time >8 hours | 1.58 | (0.71 , 3.14) | 0.23 | 1.53 | (0.67 , 3.15) | 0.27 |
| Sleep efficiency (ref: ≥80% ) | --- | --- | --- | --- | --- | --- |
| Sleep efficiency <80% | 1.22 | (0.75 , 1.91) | 0.41 | 1.09 | (0.66 , 1.76) | 0.72 |
| Wake after sleep onset (ref: <90 minutes) | --- | --- | --- | --- | --- | --- |
| Wake after sleep onset ≥ 90 minutes | 1.22 | (0.76 , 1.91) | 0.39 | 1.12 | (0.68 , 1.80) | 0.63 |
| Sleep latency (ref: <30 min) | --- | --- | --- | --- | --- | --- |
| Sleep latency ≥30min | 1.05 | (0.66 , 1.63) | 0.84 | 0.87 | (0.53 , 1.38) | 0.56 |

Adjusted for age, race, education, smoking, depressive symptoms, obesity (BMI ≥30), count of chronic health conditions, modified Mini-Mental State Examination (3MS) score, benzodiazepine use, antidepressant use, and baseline measures of the outcome.

*Baseline refers to Sleep Visit; Follow-up refers to Visit 3. OR refers to Odds Ratio. 95% CI refers to 95% Confidence Interval. IADL: instrumental activities of daily living.

**Table 5.**

Association between sleep parameters and change in chair stand time from baseline to follow-up*

| | Unadjusted Models | | | Adjusted Models | | |
|---|---|---|---|---|---|---|
| | Change in chair stand time | | | Change in chair stand time | | |
| | Beta | 95% CI | P-value | Beta | 95% CI | P-value |
| Total sleep time (ref: 6–8 hours) | --- | --- | --- | --- | --- | --- |
| Total sleep time <6 hours | 0.17 | (−0.14 , 0.48) | 0.29 | 0.03 | (−0.24 , 0.31) | 0.81 |
| Total sleep time >8 hours | 0.44 | (−0.11 , 0.99) | 0.12 | 0.28 | (−0.21 , 0.77) | 0.26 |
| Sleep efficiency (ref: ≥80% ) | --- | --- | --- | --- | --- | --- |
| Sleep efficiency <80% | 0.01 | (−0.30 , 0.33) | 0.93 | −0.01 | (−0.29 , 0.27) | 0.93 |
| Wake after sleep onset (ref: <90 minutes) | --- | --- | --- | --- | --- | --- |
| Wake after sleep onset ≥ 90 minutes | 0.01 | (−0.30 , 0.33) | 0.93 | 0.07 | (−0.21 , 0.34) | 0.63 |
| Sleep latency (ref: <30 min) | --- | --- | --- | --- | --- | --- |
| Sleep latency ≥30min | 0.41 | (0.11 , 0.71) | 0.01 | 0.26 | (−0.01 , 0.52) | 0.06 |

Adjusted for age, race, education, smoking, depressive symptoms, obesity (BMI ≥30), count of chronic health conditions, modified Mini-Mental State Examination (3MS) score, benzodiazepine use, antidepressant use, and baseline measures of the outcome.

*Baseline refers to Sleep Visit; Follow-up refers to Visit 3. β refers to the Beta unstandardized regression coefficient estimate.

**Table 6.**

Association between sleep parameters and change in gait speed from baseline to follow-up*

| | Unadjusted Models | | | Adjusted Models | | |
|---|---|---|---|---|---|---|
| | Change in gait speed | | | Change in gait speed | | |
| | β | 95% CI | P-value | β | 95% CI | P-value |
| Total sleep time (ref: 6–8 hours) | --- | --- | --- | --- | --- | --- |
| Total sleep time <6 hours | −0.03 | (−0.05 , −0.01) | 0.01 | 0.03 | (−0.04 , −0.01) | <.001 |
| Total sleep time >8 hours | −0.01 | (−0.04 , 0.03) | 0.74 | 0.00 | (−0.03 , 0.03) | 0.96 |
| Sleep efficiency (ref: ≥80% ) | --- | --- | --- | --- | --- | --- |
| Sleep efficiency <80% | −0.02 | (−0.04 , 0.00) | 0.13 | −0.01 | (−0.03 , 0.00) | 0.14 |
| Wake after sleep onset (ref: <90 minutes) | --- | --- | --- | --- | --- | --- |
| Wake after sleep onset ≥ 90 minutes | −0.01 | (−0.03 , 0.01) | 0.29 | −0.01 | (−0.03 , 0.01) | 0.18 |
| Sleep latency (ref: <30 min) | --- | --- | --- | --- | --- | --- |
| Sleep latency ≥30min | 0.00 | (−0.02 , 0.02) | 0.92 | 0.00 | (−0.02 , 0.01) | 0.70 |

Adjusted for age, race, education, smoking, depressive symptoms, obesity (BMI ≥30), count of chronic health conditions, modified Mini-Mental State Examination (3MS) score, benzodiazepine use, antidepressant use, and baseline measures of the outcome.

*Baseline refers to Sleep Visit; Follow-up refers to Visit 3. β refers to the Beta unstandardized regression coefficient estimate.

**Table 7.**

Association between sleep parameters and change in grip strength from baseline to follow-up*

| | Unadjusted Models | | | Adjusted Models | | |
|---|---|---|---|---|---|---|
| | Change in grip strength | | | Change in grip strength | | |
| | β | 95% CI | P-value | β | 95% CI | P-value |
| Total sleep time (ref: 6–8 hours) | --- | --- | --- | --- | --- | --- |
| Total sleep time <6 hours | −0.37 | (−0.90 , 0.15) | 0.16 | −0.41 | (−0.92 , 0.09) | 0.11 |
| Total sleep time >8 hours | 0.29 | (−0.64 , 1.23) | 0.54 | 0.48 | (−0.41 , 1.37) | 0.29 |
| Sleep efficiency (ref: ≥80% ) | --- | --- | --- | --- | --- | --- |
| Sleep efficiency <80% | 0.02 | (−0.52 , 0.55) | 0.95 | 0.07 | (−0.45 , 0.58) | 0.80 |
| Wake after sleep onset (ref: <90 minutes) | --- | --- | --- | --- | --- | --- |
| Wake after sleep onset ≥ 90 minutes | 0.18 | (−0.35 , 0.71) | 0.51 | 0.17 | (−0.34 , 0.68) | 0.51 |
| Sleep latency (ref: <30 min) | --- | --- | --- | --- | --- | --- |
| Sleep latency ≥30min | −0.32 | (−0.83 , 0.19) | 0.22 | −0.18 | (−0.67 , 0.30) | 0.45 |

Adjusted for age, race, education, smoking, depressive symptoms, obesity (BMI ≥30), count of chronic health conditions, modified Mini-Mental State Examination (3MS) score, benzodiazepine use, antidepressant use, and baseline measures of the outcome.

*Baseline refers to Sleep Visit; Follow-up refers to Visit 3. β refers to the Beta unstandardized regression coefficient estimate.

**Table 8.**

Association between sleep parameters and change in best narrow walk pace from baseline to follow-up*

| | Unadjusted Models | | | Adjusted Models | | |
|---|---|---|---|---|---|---|
| | Change in best narrow walk pace | | | Change in best narrow walk pace | | |
| | β | 95% CI | P-value | β | 95% CI | P-value |
| Total sleep time (ref: 6–8 hours) | --- | --- | --- | --- | --- | --- |
| Total sleep time <6 hours | 0.00 | (−0.02 , 0.03) | 0.71 | 0.00 | (−0.02 , 0.03) | 0.75 |
| Total sleep time >8 hours | -0.02 | (−0.07 , 0.03) | 0.40 | −0.01 | (−0.05 , 0.03) | 0.59 |
| Sleep efficiency (ref: ≥80% ) | --- | --- | --- | --- | --- | --- |
| Sleep efficiency <80% | 0.00 | (−0.02 , 0.03) | 0.81 | 0.00 | (−0.02 , 0.03) | 0.81 |
| Wake after sleep onset (ref: <90 minutes) | --- | --- | --- | --- | --- | --- |
| Wake after sleep onset ≥ 90 minutes | 0.00 | (−0.03 , 0.02) | 0.81 | −0.01 | (−0.03 , 0.02) | 0.50 |
| Sleep latency (ref: <30 min) | --- | --- | --- | --- | --- | --- |
| Sleep latency ≥30min | −0.01 | (−0.04 , 0.02) | 0.44 | −0.01 | (−0.03 , 0.01) | 0.46 |

Adjusted for age, race, education, smoking, depressive symptoms, obesity (BMI ≥30), count of chronic health conditions, modified Mini-Mental State Examination (3MS) score, benzodiazepine use, antidepressant use, and baseline measures of the outcome.

*Baseline refers to Sleep Visit; Follow-up refers to Visit 3. β refers to the Beta unstandardized regression coefficient estimate.