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Self-reported long sleep in older adults is closely related to objective time in bed

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Abstract

Although self-reported long sleep is associated with increased morbidity and mortality, little is known about the objective sleep patterns and daytime functioning of long sleepers, particularly those aged 50 years. Our primary aim was to compare the objective and subjective sleep patterns of a sample ($n = 35$) of middle- to older-aged adults who reported sleeping 8.5 h per night. A secondary aim was to characterize the mood and functioning of the sample. Over a 2-week period, sleep was recorded via actigraphy and a daily diary. Sleepiness was assessed daily. At the conclusion of the 2-week period, daytime sleepiness, mood, and quality of life were assessed. Measures of sleep and functioning were compared with available representative data. In the sample, actigraphic total sleep time (TST; 7.35 ± 0.97 h) was approximately 60 min greater than age-related representative values but substantially less than diary-assessed TST (8.59 ± 0.74 h) and survey-assessed TST (8.92 ± 0.78 h). Survey and diary-based subjective TST assessments agreed more closely with actigraphic time in bed (TIB; 9.11 ± 0.72 h) than TST, and correlations between subjective TST and actigraphic TIB were similar to those between subjective and actigraphic TST. Measures of mood, sleepiness, and daytime functioning were similar to population-representative values. These results suggest that, among middle- to older-aged adults, self-reported long sleep is primarily indicative of long TIB, but it also represents long objective sleep duration, particularly in comparison to age-matched data. Findings of little functional impairment corroborated previous descriptions of older long sleepers.

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Keywords

actigraphy; aged; long sleeper; middle-aged; time in bed

INTRODUCTION

There is consistent epidemiologic evidence that self-reported long sleep (≥ 8 h per night) is associated with increased mortality¹ and numerous morbidities, including hypertension,² stroke,³ coronary heart disease,³ and diabetes.⁴ These hazards have increased in a dose-response pattern with increases in sleep duration beyond 7 h,¹ and have persisted following control for multiple factors, including sleep apnea, depression, health status, and medication use.²

Notwithstanding these data, the hypothesis that long sleep could be hazardous has not been widely accepted, perhaps particularly since 8 h of sleep is commonly assumed to be ideal for health. Of course, causality cannot be established with epidemiologic studies, and the risks associated with long sleep might be explained by other factors.^{5,6}

An important limitation of the extant literature is that there has been remarkably little systematic investigation of those who report long sleep durations. For example, it is uncertain the extent to which self-reported long sleep is indicative of physiologic sleep or time in bed (TIB). A focus on long sleepers over the age of 50 years seems especially important since the prevalence of self-reported long sleep is greater for older *versus* younger adults.^{1,3} Moreover, although the association of long sleep with morbidity/mortality has been established across all age groups,¹ most of the mortality linked with long sleep has been observed in adults older than 50 years of age.⁷

In addition to its established associations with somatic morbidity, long sleep has also been associated with psychological morbidity. Early studies involving young adults found that long sleepers had more psychopathology than normal-duration sleepers,⁸ and population-based studies have documented an association between long sleep and mental health problems such as dementia⁹ and depression.¹⁰ We are aware of only one non-epidemiologic study of this topic in older adults, which found no signs of psychological maladjustment (e.g. depression, anxiety, neuroticism) in healthy self-reported long sleepers (≥ 8 h) *versus* short sleepers (< 6 h) ages 55–87 years.¹¹ However, the study was limited to self-report data without comparison to average duration sleepers, who have less morbidity than short sleepers.²

The primary aim of the present report was to assess and compare the subjective and objective sleep patterns of a sample of adults ages 50–70 years who reported sleeping ≥ 8.5 h per night. A secondary purpose of the report was to characterize the mood and daytime functioning of the sample by using standardized questionnaires of depression, daytime sleepiness, health-related quality of life, and daytime activity, and to compare these values with available age-matched representative data. It was hypothesized that the long TST reported by the sample would be more indicative of long objective TIB, and that the mood and daytime functioning would be similar to age-matched representative data.

METHODS

Participant screening

Individuals aged 50–70 years who reported sleeping 8.5 h per night were recruited for participation in the study. Participants were recruited for a subsequent experimental study involving chronic moderate TIB restriction. The experimental study has been described elsewhere.^{12,13}

Initial screening was based on a packet of questionnaires that was mailed to prospective participants along with an informed consent approved by the Institutional Review Board at the University of South Carolina. Potential participants were excluded if the questionnaires indicated insufficient sleep duration (<8.5 h/night), suspected significant sleep apnea (e.g. morbid obesity, heavy snoring), diabetes, excessive daytime napping (i.e. 60 min per day), recent shift work experience or travel across multiple time zones, excessive daytime sleepiness (i.e. Epworth Sleepiness Scale [ESS]¹⁴ score >10), significant depression (e.g. Geriatric Depression Scale [GDS]¹⁵ score >10), or self-reported use of selected medications (e.g. hypnotics, antipsychotics). The intent of these criteria was to exclude participants who might be most at risk of negative consequences in the subsequent 8-week TIB restriction intervention.^{12,13} However, other morbidities (e.g. hypertension, dyslipidemia) were not exclusions, nor were mild/moderate snoring or prior chronic diseases (e.g. cancer).

Assessments of self-reported total sleep time (TST), sleep onset latency (SOL), and wakefulness after sleep onset (WASO) were obtained from the initial screening questionnaire with the following questions, referring to the previous seven nights of sleep: “how many hours were you asleep each night?” (TST); “how many minutes, on average, did it take you to fall asleep?” (SOL); and “how many hours (or minutes) were you awake each night after initially falling asleep?” (WASO). Time in bed (TIB) was calculated based on the participant’s reported times of going to bed and arising from bed. In addition, participants were asked questions regarding sleep quality, sleep sufficiency, and the frequency of experiencing difficulty initiating sleep, early morning awakening, and difficulty awakening in the morning. These screening questions were expected to resemble the questions used in epidemiologic surveys that have associated long sleep with morbidity and mortality.

Prospective participants who met the initial screening criteria then received a physical examination and interview by a board-certified sleep physician (RKB) to assess their general health, current medication use, symptoms of sleep disorders, and possible medical causes of long sleep. Exclusion for diabetes (i.e. fasting glucose 126 mg/dL; 2-h glucose 200 mg/dL) was also implemented with an oral glucose tolerance test.

Objective and subjective sleep assessment

Each participant’s sleep habits were recorded for 2 consecutive weeks in his/her usual environment with actigraphy and a sleep diary. Participants were instructed to maintain their normal sleep and napping habits and their usual intake of caffeine, alcohol, and medications.

Objective sleep/wake status was monitored continuously via wrist actigraphic recording (Octagonal Basic Motionlogger; Ambulatory Monitoring, Ardsley, NY, USA). Measures of

TIB, TST, SOL, WASO, and sleep efficiency (SE) were obtained. In addition, daytime napping was scored based upon actigraphic data that showed clear and prolonged reductions in activity (i.e. >10 min).

Each morning, participants were asked to report in the sleep diary the time of “lights out trying to sleep,” the amount of time it took to fall asleep (SOL), the amount of time awake following initial sleep onset and before awakening for the final time (WASO), the “final get-out-of-bed time,” and TST. TIB was calculated as the interval from the “time of lights out trying to sleep” to “final get-out-of-bed time.” In addition, insomnia was rated on a 100-mm visual analogue scale (0 = none, 100 = worst possible). Self-reported daytime napping duration also was noted in the diary daily.

Daytime functioning assessment

Daytime sleepiness was assessed every 4 h during wakefulness each day with the Stanford Sleepiness Scale (SSS), in which sleepiness is rated from 1 (feeling active and vital, alert, wide awake) to 7 (almost in reverie, sleep onset soon, lost struggle to remain awake).¹⁶ At the end of the 2-week period, participants completed the GDS, the ESS, the Medical Outcomes Study Short-Form Health Survey (SF-36),¹⁷ and a modified Functional Outcomes of Sleepiness Questionnaire (FOSQ).¹⁸ The GDS is a 30-item scale that assesses depressive symptoms specific to an older community-dwelling population.¹⁵ The ESS is a measure of daytime sleepiness, and assesses the likelihood of falling asleep during eight everyday sedentary activities (e.g. reading, driving).¹⁴ The SF-36 is a 36-item scale that evaluates a variety of health-related quality of life concepts.¹⁷ The modified FOSQ is a 25-item scale that estimates how daytime sleepiness affects one’s ability to perform certain tasks in the dimensions of general productivity, social outcome, activity level, and vigilance.¹⁸

Data analysis

Data were analyzed using SPSS for Windows (version 15.0; Chicago, IL, USA). The statistical significance criterion was set at $P < 0.01$ to reduce the chance of type I error associated with multiple comparisons. All data are presented as mean $\pm$ SD.

Sample representativeness—To address whether the study’s inclusion criteria resulted in an abnormal sample of older long sleepers, the included sample of long sleepers was compared against those individuals who were excluded from participation for reasons other than having insufficient self-reported sleep duration (e.g. suspected sleep apnea, diabetes) via independent *t*-test comparisons on the following variables assessed at initial screening: age, body mass index (BMI), TIB, TST, ESS, and GDS.

Sleep variables—Measures of TIB, TST, SOL, WASO, and SE were obtained from the screening questionnaire, the experimental sleep diary, and actigraphic data. Typically, actigraphic TIB was obtained by the participants’ use of event markers to indicate the time at which they went to bed with the intention of going to sleep. However, when this was not available, actigraphic TIB was determined by inspection of activity and light recordings around the self-reported times of going to and arising from bed. Also assessed via actigraphy were the number of nighttime awakenings and sleep continuity, which was defined as the

percentage of time spent asleep from initial sleep onset to final wake time. Actigraphic sleep/wake status was estimated from the Proportional Integrating Mode using a validated algorithm^{19,20} associated with Actiwatch software (version 1.12; Ambulatory Monitoring), with some editing (e.g. for time off wrist). Across the 14-day period, median within-subject values for each of the actigraphic and self-reported sleep variables were calculated and then averaged across all participants.

Due to malfunctioning activity sensors that resulted in inaccurately low wrist movement recordings, actigraphic data for seven of the 42 participants were not available for analysis. Therefore, participants without valid actigraphic data were not included in the final analyses, and all data presented are from the common sample with both actigraphic and sleep diary data ($n = 35$).

The various measurements of TIB and TST were compared with three separate analyses. Differences between survey, diary, and actigraphic measurements of TIB and TST were evaluated with paired t -tests to indicate whether a particular measurement method over- or underestimated TIB or TST relative to the other. Associations between these variables were assessed with Spearman rank-order correlations (r_s). Agreement between different measurements of TIB and TST were explored with Bland-Altman plots, with the difference between the two measurements plotted against the mean of the two measurements. Limits of agreement for these plots were calculated as the mean difference ± 1.96 SD.²¹

Actigraphic data were compared with published objective sleep data of representative samples using polysomnographic (PSG)²² and actigraphic data.^{23–27} Representative values of TST, SOL, WASO, and SE were averaged across studies for individuals aged 50–70 years and compared with data from the present study using one-sample t -tests.

Questionnaire measures—For each day of assessment, mean within-subject SSS ratings were determined. Because many participant SSS ratings did not have normal distributions, median within-subject daily SSS ratings across the 2-week period were then averaged across all subjects. An exhaustive search of the literature was undertaken to obtain published representative data of apparently healthy adults aged 50–70 years for each of the questionnaires used. For each questionnaire, participant values were compared to available published representative values by one-sample t -tests.

RESULTS

Participant characteristics

A common sample of 35 individuals (25 female, 10 male) provided complete data for the 2-week assessment. Mean age was 59.9 ± 5.5 years. Mean height was 1.7 ± 0.1 m, mean body weight was 72.9 ± 12.7 kg, and mean BMI was 25.6 ± 3.6 kg/m². The majority of participants classified themselves as non-Hispanic White ($n = 27$). Others classified themselves as non-Hispanic Black ($n = 3$), Asian/Pacific Islander ($n = 3$), and Middle Eastern/“other” ($n = 2$).

Many potential participants were excluded after initial review of screening questionnaires ($n = 177$). The vast majority of exclusions were due to responses that indicated < 8.5 h sleep ($n = 104$), but other common exclusions were for suspected sleep apnea ($n = 31$) or significant depression ($n = 18$). Individuals who were excluded for reasons other than insufficient sleep ($n = 73$) had significantly higher BMI values (30.1 ± 6.6 vs 25.6 ± 3.6 kg/m²; $P < 0.001$), and had significantly higher ESS scores (6.7 ± 4.5 vs 4.1 ± 2.9 ; $P = 0.003$) and GDS scores (5.1 ± 5.0 vs 2.2 ± 2.4 ; $P = 0.002$) than the experimental sample ($n = 35$). However, the included participants and individuals excluded for reasons other than insufficient sleep did not differ significantly in age, self-reported TIB, or self-reported TST.

Screening data

At screening, participants reported spending an average of 9.47 ± 0.83 h in bed each night and sleeping an average of 8.92 ± 0.78 h at night. Other self-reported screening data suggested generally good sleep among the participants. For instance, self-reported SOL was 13.34 ± 11.00 min and WASO was 13.02 ± 17.39 min (Table 1). Participants reported that during the week prior to screening, they experienced difficulty staying awake until bedtime on 0.51 ± 0.82 nights, difficulty falling asleep on 0.54 ± 0.89 nights, and had early awakenings on 0.54 ± 1.27 mornings. All but one participant ($n = 34$) rated their sleep quality as being “moderately” to “very” satisfactory. Furthermore, the majority of participants ($n = 29$) indicated that they got “just enough sleep,” whereas self-assessments of getting “too much sleep” and “too little sleep” were reported by only three participants each.

Although briefly screened for significant disease and sleep disorders, the participants had a notable history of morbidity. For instance, 11 individuals had hypertension, eight were being treated for elevated cholesterol, five were under treatment for hypothyroidism, and four had a history of cancer. In fact, 20 of the 35 participants reported one or more chronic health conditions that were currently under treatment. The prevalence of these various morbidities in this sample was similar to respective national age-associated prevalence rates.^{28,29}

Objective and subjective sleep assessment

Actigraphic data—Mean TIB over the 2 weeks of recording was 9.11 ± 0.72 h. In contrast, mean TST was only 7.35 ± 0.97 h (Table 1). Although much less than TIB, actigraphic TST was significantly greater than representative values^{22–27} for adults ages 50–70 years (actigraphic: 6.11 h, $P < 0.001$; PSG: 6.36 h, $P < 0.001$). Mean SOL in the sample (11.04 ± 6.24 min) was significantly less than age-matched representative values (actigraphic: 15.54 min, $P < 0.001$; PSG: 17.18 min, $P < 0.001$). Mean WASO (86.40 ± 37.92 min) was significantly greater than PSG representative values (68.17 min; $P = 0.007$), but not significantly different from actigraphic representative values (78.55 min; $P = 0.229$). Sleep efficiency ($81.40 \pm 7.93\%$) was not significantly different from age-matched representative values (actigraphic: 79.60%, $P = 0.196$; PSG: 84.80%, $P = 0.016$). Sleep continuity was $83.71 \pm 7.33\%$, and there were 24.06 ± 7.06 actigraphic awakenings per night. Participants napped during the daytime for 16.89 ± 21.66 min per day.

Sleep diary data—Over the 2 weeks of baseline recording, mean diary TIB was 9.14 ± 0.68 h. Mean subjective TST was 8.59 ± 0.74 h (Table 1). Mean SOL and WASO were

10.64 $\pm$ 7.89 min and 8.39 $\pm$ 7.17 min, respectively. Mean insomnia on the 100-mm scale was 5.46 $\pm$ 5.79 (i.e. close to none). Participants reported napping in the daytime for 6.50 $\pm$ 9.56 min per day.

Comparisons of various measurements of TIB and TST

Screening TIB was significantly greater than diary TIB (average difference: 0.33 $\pm$ 0.49 h; $t_{34} = 3.992$, $P < 0.001$) and actigraphic TIB (average difference: 0.36 $\pm$ 0.61 h; $t_{34} = 3.435$, $P = 0.002$), whereas diary TIB and actigraphic TIB were not significantly different (average difference: 0.03 $\pm$ 0.31 h; $t_{34} = 0.488$, $P = 0.629$) (Fig. 1, Table 2). Significant correlations ($P < 0.001$) were found between each of these measures of TIB, with the strongest association noted between diary and actigraphic measurements of TIB ($r_S = 0.901$, $P < 0.001$) (Table 3).

Screening TST was significantly greater than diary TST (average difference: 0.33 $\pm$ 0.60 h; $t_{34} = 3.307$, $P = 0.002$) and actigraphic TST (average difference: 1.57 $\pm$ 0.82 h; $t_{34} = 11.295$, $P < 0.001$) (Fig. 1, Table 2). Diary TST was also significantly greater than actigraphic TST (average difference: 1.24 $\pm$ 0.81 h; $t_{34} = 9.009$, $P < 0.001$). Significant correlations ($P < 0.001$) were found between each of these measures of TST (Table 3), with the strongest association occurring with screening and actigraphic TST ($r_S = 0.684$, $P < 0.001$).

Screening TST was remarkably similar to actigraphic TIB (average difference: -0.19 ± 0.63 h; $t_{34} = 1.752$, $P = 0.089$), though the correlation between the two measurements was moderate in strength ($r_S = 0.585$, $P < 0.001$). Diary TST was significantly yet only modestly less than actigraphic TIB (average difference: -0.52 ± 0.42 h; $t_{34} = 7.269$, $P < 0.001$), with strong correlation between the two measurements ($r_S = 0.813$, $P < 0.001$).

Daytime functioning assessment

Sleepiness—Mean SSS score was 2.03 $\pm$ 0.70, whereas the mean ESS score was 4.37 $\pm$ 3.12. Mean SSS values were comparable to published values of adults aged 50–70 years (1.83 and 2.30, respectively).^{30,31} Participant ESS values were comparable to (4.93)³² or significantly lower than (5.85 and 8.12–8.35, respectively)^{33,34} other published reports of samples of similar ages.

Depression—Mean GDS score was 2.90 $\pm$ 3.13. GDS scores were significantly lower than previously published representative values for adults aged 50–70 years (5.75).¹⁵

Health-related quality of life—Means for each of the eight SF-36 subscales were as follows: bodily pain, 84.29 $\pm$ 18.34; general health, 81.77 $\pm$ 15.09; mental health, 87.20 $\pm$ 12.64; physical functioning, 88.86 $\pm$ 16.05; role-emotional, 96.19 $\pm$ 10.76; role-physical, 93.57 $\pm$ 21.30; social functioning, 93.93 $\pm$ 15.86; vitality, 75.43 $\pm$ 16.06. All subscale scores were similar to or higher (i.e. indicating better functioning) than representative values (bodily pain: 67.51 and 75.02–77.08, respectively; general health: 64.62 and 68.26–68.64, respectively; mental health: 75.01 and 73.78–75.01, respectively; physical function: 76.24 and 73.78–77.01, respectively; role-emotional: 80.26 and 77.72–79.39, respectively; role-

physical: 73.66 and 78.81–80.03, respectively; social functioning: 81.37 and 80.05–81.28, respectively; vitality: 60.37 and 64.78–66.72, respectively).^{17,35}

Functional outcomes of sleepiness questionnaire—FOSQ total score was 15.09 ± 0.95 , and subscale scores were as follows: activity level, 3.65 ± 0.38 ; general productivity, 3.82 ± 0.26 ; social outcome, 3.93 ± 0.16 ; vigilance, 3.70 ± 0.43 . Participant activity level sub-scale scores were significantly lower (i.e. indicating greater impairment) than previously reported values for healthy older adults (3.81).³² No other subscale scores were significantly different from previously published reports (FOSQ total: 15.39; general productivity: 3.89; social outcome: 3.97; vigilance: 3.76).³²

DISCUSSION

In this sample of middle- to older-aged self-reported long sleepers, actigraphic TST was significantly greater than age-matched representative objective data, but far less than subjectively reported by the participants. Survey- and diary-derived estimates of TST were more similar to actigraphic TIB than actigraphic TST. The participants were characterized by levels of mood and daytime functioning that were generally similar to representative data.

Whereas participants reported sleep durations of 8.96 ± 0.76 h and 8.59 ± 0.74 h on the screening questionnaire and diary, respectively, they slept only 7.35 ± 0.97 h per night according to actigraphic recording. Conversely, the participants underestimated their WASO subjectively compared with actigraphic assessment. However, the increased actigraphic WASO observed in the sample seemed to be attributable to long TIB, as SE did not differ between the sample and representative values.

The overestimation of sleep duration observed in the present sample is in agreement with other studies that have compared subjective and objective measurements of sleep duration.^{26,36–38} In particular, two recent studies found that samples of predominantly middle- to older-aged adults with normal sleep durations slept up to 60 min less than what they subjectively reported.^{37,38} The present findings extend these similar results to older self-reported long sleepers. Moreover, these results may help explain the paradox in which the prevalence of self-reported long sleep is higher among adults over 50 years^{1,3} despite the well-established age-related decline in objective sleep duration.²²

Our data indicate that self-reported long sleep in middle- to older-aged adults is more indicative of objective TIB than TST. Both screening and diary TST assessments were closer in magnitude to actigraphic TIB than they were to actigraphic TST, though correlations were generally similar between the pairs of measures. Indeed, screening and diary-based estimates of TST were approximately 95 min and 75 min greater than actigraphic TST, respectively, but only 10 min and 30 min different from actigraphic TIB, respectively. Moreover, the magnitude of variation between subjective TST and actigraphic TIB (Fig. 1e,f) was much less than between subjective TST and actigraphic TST (Fig. 1c,d). That self-reported long sleep is more indicative of long TIB could be an important

distinction, as epidemiologic studies of the risks of long sleep have relied mostly upon self-reported measures of sleep duration.

However, the extent to which the risks of long sleep are associated with long sleep per se or long TIB remains unclear. In the present sample, it is noteworthy that actigraphic TST was still approximately 60 min greater than age-associated representative values. When coupled with the strong correlation observed in the present study between actigraphic TST and screening TST ($r_s = 0.684$), it can be surmised that reported long sleep duration is likewise indicative of relatively long physiologic sleep in epidemiologic studies.

In general, participants were found to have daytime functioning values that were similar or even superior to age-matched representative data, and sleep complaints were minimal.³⁹ Indeed, the only measure that suggested subpar functioning was in the FOSQ Activity Level subscale, which is in agreement with other recent evidence associating long self-reported sleep with low levels of daytime physical activity and fitness.^{40,41} Our findings of normal daytime functioning and lack of significant sleep complaints in the present sample contrast with some previous studies of younger long sleepers that suggested functional impairment (e.g. disturbed mood, anxiety) and frequent sleep disturbance.^{8,42} However, our results are in general agreement with those of Fichten *et al.*¹¹ who found no evidence of psychological maladjustment or sleep complaints in a healthy sample of older long sleepers.

Due to the paucity of study of older long sleepers, the health status of this population is not clear. The exclusion criteria of the study may have resulted in a sample that was healthier than the average middle- to older-aged long sleeper. For example, the experimental sample had lower BMI, ESS and GDS scores than individuals who were excluded from participation for reasons other than insufficient sleep duration. However, the sample did not possess exceptional health, as morbidity prevalence was similar to that of the general population,^{28,29} and over one-half of the participants were currently receiving treatment for a chronic health condition. Evidence that the risks of long sleep have persisted following control for current health status⁴³ suggests that even apparently healthy long sleepers might also be at risk.

The appropriateness of comparing the sample's characteristics to those of age-matched representative data may be questioned. However, in many cases, the experimental sample was compared against data from studies that employed similar health screening procedures.^{15,30,32,33} Nevertheless, it would have been desirable to recruit a population-representative sample of age-matched average-duration sleepers for comparison with these long sleepers.

An additional limitation of the study was the use of actigraphy instead of PSG for objective assessment of sleep. However, the algorithm used in the present study has been previously validated against PSG using similar actigraphs.^{19,20} Moreover, actigraphy is preferred for detection of daytime napping and for long-term monitoring of sleep, which occurred for the present study and its subsequent experimental arm.^{12,13}

In summary, this study provided a detailed view of a sample of middle- to older-aged self-reported long sleepers. The mood and functioning of these individuals were generally

similar to other middle- to older-aged adults. Although the participants had relatively long durations of actigraphically recorded sleep (~7.3 h) for their age, they were distinct chiefly for prolonged TIB (>9 h). These data indicate that self-reported long sleep duration may be more indicative of long TIB, which is noteworthy as the health risks associated with long sleep are commonly derived from self-reported measures. Moreover, the general daytime functioning of these individuals implies that long sleep can be independent of functional limitations.

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Figure 1.

Bland-Altman plots of the differences in methods of measurement of time in bed (TIB) and total sleep time (TST). Solid horizontal line indicates the mean difference between the two methods of measurement. Dashed horizontal lines indicate the 95% limits of agreement (mean difference ± 1.96 SD). (a) Screening TIB and actigraphic TIB; (b) diary TIB and actigraphic TIB; (c) screening TST and actigraphic TST; (d) diary TST and actigraphic TST; (e) screening TST and actigraphic TIB; (f) diary TST and actigraphic TIB.

Table 1

Self-reported screening, self-reported sleep diary, and actigraphic measures of sleep

Sleep measure	Participant sleep data			Objective age-matched representative values		
	Screening	Sleep diary	Actigraphy	Actigraphy	PSG	
TIB (h)	9.47 ± 0.83	9.14 ± 0.68 *	9.11 ± 0.72 *	–	–	
TST (h)	8.92 ± 0.78	8.59 ± 0.74 *	7.35 ± 0.97 **, **	6.11 ***	6.36 ***	
SOL (min)	13.34 ± 11.00	10.64 ± 7.89	11.04 ± 6.24	15.54 ***	17.18 ***	
WASO (min)	13.02 ± 17.39	8.39 ± 7.17	86.40 ± 37.92 **, **	78.55	68.17 ***	
SE (%)	94.41 ± 5.26	94.03 ± 3.83	81.40 ± 7.93 **, **	79.60	84.80	
Daytime napping (min)	–	6.50 ± 9.56	16.89 ± 21.66	–	–	
Insomnia (0–100)	–	5.46 ± 5.79	–	–	–	

* Indicates a significant difference from the respective screening value ($P < 0.01$).

** Indicates a significant difference from the respective sleep diary value ($P < 0.01$).

*** Indicates a significant difference between the sleep measure and its actigraphic or polysomnographic representative value ($P < 0.01$).

PSG, polysomnography; SE, sleep efficiency; SOL, sleep onset latency; TIB, time in bed; TST, total sleep time; WASO, wakefulness after sleep onset.

Table 2

Magnitude of disagreement between different measures of time in bed and total sleep time

Measurement comparisons	Average difference (h)
Screening TIB – diary TIB *	$0.33 \pm 0.49^*$
Screening TIB – actigraphic TIB *	$0.36 \pm 0.61^*$
Diary TIB – actigraphic TIB	0.03 ± 0.31
Screening TST – diary TST *	$0.33 \pm 0.60^*$
Screening TST – actigraphic TST *	$1.57 \pm 0.82^*$
Diary TST – actigraphic TST *	$1.24 \pm 0.81^*$
Screening TST – actigraphic TIB	-0.19 ± 0.63
Diary TST – actigraphic TIB *	$-0.52 \pm 0.42^*$

* Indicates a significant difference between the two measurements as compared by paired *t*-tests ($P < 0.01$).

TIB, time in bed; TST, total sleep time.

Table 3

Correlations between different measures of time in bed and total sleep time

	Screening TIB	Screening TST	Diary TIB	Diary TST	Actigraphic TIB	Actigraphic TST
Screening TIB		0.611 *	0.747 *	0.656 *	0.645 *	0.331
Screening TST			0.687 *	0.581 *	0.585 *	0.684 *
Diary TIB				0.836 *	0.901 *	0.650 *
Diary TST					0.813 *	0.557 *
Actigraphic TIB						0.652 *

* Indicates a significant association between the two variables ($P < 0.01$) using Spearman rank-order correlations (r_s).

TIB, time in bed; TST, total sleep time.