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SCIENTIFIC INVESTIGATIONS

Discrepancies between self-reported and device-measured sleep parameters in adults with multiple sclerosis

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Study Objectives: Sleep problems are a common consequence of multiple sclerosis; however, there is limited evidence regarding the agreement between device-measured and self-reported sleep parameters in adults with multiple sclerosis. The present study examined the agreement between self-reported and device-measured parameters of sleep quality in a sample of adults with multiple sclerosis.

Methods: Participants (n = 49) completed a 7-day sleep diary and wore a wrist-worn ActiGraph GT3×+ (ActiGraph Corp., Pensecola, FL) for seven consecutive nights to quantify self-reported and device-measured sleep parameters, respectively.

Results: There was a significant discrepancy between self-reported and device-measured parameters of total time in bed (mean difference = 19.8 [51.3] min), sleep onset latency (mean difference = 22.2 [19.5] min), and frequency of awakenings during the night (mean difference = 12.8 [6.8]). Intraclass correlation estimates indicated poor agreement between methods on most parameters, except for total time in bed (intraclass correlation = 0.80). Bland-Altman plots suggested that total time in bed and total sleep time had acceptable levels of agreement and linear regression analyses indicated that sleep onset latency ($F = 113.91$, B = −1.34, $P < .001$), number of awakenings ($F = 543.34$, B = 1.85, $P < .001$), and sleep efficiency ($F = 18.39$, B = −0.77, $P < .001$) had significant proportional bias.

Conclusions: Our results draw attention to the discrepancies between sleep parameter measurements and highlight the importance of including both self-report and device-measured outcomes for a complete and accurate representation of sleep in adults with multiple sclerosis.

Keywords: sleep, multiple sclerosis, sleep diary, actigraphy

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BRIEF SUMMARY

Current Knowledge/Study Rationale: Previous studies in the general population and other clinical populations suggest there may be discrepancies between self-report and device-measured sleep parameters. There is an unmet need to evaluate the agreement between device-measured and self-reported sleep metrics in adults with multiple sclerosis.

Study Impact: Identifying the most appropriate method of quantifying sleep parameters may offer more accurate identification and quantification of sleep problems in this population. Our results draw attention to the discrepancies that can occur with only one type of measurement and highlight the importance of including both self-report and device-measured sleep parameters for a complete and accurate representation of sleep in adults with multiple sclerosis.

INTRODUCTION

Multiple sclerosis (MS) is an immune-mediated disease of the central nervous system with a prevalence of nearly 1 million adults in the United States[1] and 2.8 million people worldwide.[2] Sleep problems are a common consequence of MS, whereby 60% of adults with MS report sleep difficulties.[3] Importantly, sleep impairments can worsen other symptoms and consequences of MS3 and there is accumulating evidence that sleep disturbances negatively influence the MS disease course[4] and overall quality of life.[5] This highlights the importance of identifying and quantifying parameters of sleep quality in adults with MS.

There are a number of methods for quantifying sleep-quality parameters. Overnight polysomnography is considered the gold-standard method of measuring sleep parameters but may not reflect naturalistic sleep patterns.[6–8] There is accumulating interest in the use of devices (ie, actigraphy) and self-report methods (ie, diaries and questionnaires), as these offer feasible, cost-effective, and simple approaches for measuring parameters of sleep quality.[9–12] However, studies in the general population suggest there may be discrepancies between self-report and device-measured sleep parameters in otherwise healthy adults[13–15] and there are mixed results in clinical populations such as fibromyalgia and chronic low back pain.[16–18]

There is limited evidence regarding the agreement between device-measured and self-reported sleep parameters in adults with MS. We located one study that examined the relationship between objective and self-reported sleep parameters in a sample of 16 adults with MS.[19] That study included questionnaires for quantifying symptoms of insomnia, restless legs syndrome (RLS), and obstructive sleep apnea as outcomes of self-reported sleep rather than including an outcome of general sleep quality outside of a specific sleep disorder.[19] There is an unmet need to evaluate the agreement between device-measured and

self-reported sleep quality in adults with MS, as identifying the most appropriate method of measuring sleep quality may offer more accurate identification and quantification of sleep problems in this population.

The present study examined the agreement between self-reported and device-measured parameters of sleep quality in a sample of adults with MS. We included a 7-day sleep diary and a wrist-worn ActiGraph GT3×+ for 7 consecutive nights for quantifying parameters of self-reported and device-measured sleep, respectively. Sleep parameters included total time in bed (TIB), sleep onset latency, number of awakenings, total sleep time, and sleep efficiency as overlapping metrics of sleep quality between outcome measures. Based on the aforementioned literature, we expected acceptable agreement between methods for parameters of TIB[14] and total sleep time[13–18] but not for parameters of sleep latency,[16,18] number of awakenings, or sleep efficiency.[18]

METHODS

Participants

Data for the present study were pooled across two studies with overlapping content for generating a larger sample, and thereby yielding more power for estimating the relationship between self-reported and device-measured sleep quality in MS. Both studies recruited through a university-based patient database for targeted recruitment of individuals with MS. Letters and flyers were distributed among persons identified through the database, and interested persons contacted the research team for a brief description of the studies and screening.

One study was cross-sectional in nature and recruited participants with and without RLS.[20] Participants were included in the study if they were 18 years or older and had a diagnosis of MS. All participants were screened for symptoms associated with RLS during telephone screening[21] and participants with MS who did not present with RLS served as controls, which were matched based on age (± 5 years), sex, and disability status (± 1 point), based on the single-item Patient Determined Disease Steps.[22] Participants were excluded based on moderate or high risk for undertaking strenuous or maximal exercise or diagnosis of radiculopathy, peripheral edema, peripheral neuropathy, iron deficiency anemia, renal disease, or diabetes. The sample consisted of 37 participants (17 with MS and RLS and 20 with MS alone) who met inclusion criteria and completed all aspects of the study protocol.

The other study was a pilot-randomized controlled trial[23] that included participants who met the following inclusion criteria: (1) 18 years or older, (2) had a confirmed diagnosis of MS, (3) were relapse-free for the past 30 days, and (4) were ambulatory without assistance. As this study included an internet-based physical activity behavioral intervention specifically for adults with MS who had moderate to very severe RLS, participants were included if they had internet and email access and were nonactive, defined as not engaging in regular activity (ie, 30 minutes accumulated per day) on more than 2 days of the week for the previous 6 months. Participants were excluded based on moderate or high risk for undertaking strenuous or maximal exercise or diagnosis of radiculopathy, peripheral edema, peripheral neuropathy, iron deficiency anemia, renal disease, or diabetes. Of note, 12 participants satisfied inclusion criteria, completed baseline testing, and were included in the present study. Overall, the total sample for the present study included 49 persons with MS.

Self-reported sleep quality

We measured self-reported sleep quality using a 7-day sleep diary and the Pittsburgh Sleep Quality Index (PSQI). The 7-day diary included a standardized sleep diary designed for individuals with insomnia[24] and provided a measure of nightly self-reported sleep-quality parameters for 7 consecutive nights. The diary included items for bedtime, rise time, estimated time to fall asleep (ie, sleep onset latency in minutes), estimated number of awakenings, and estimated total sleep time for each of the 7 nights. One member of the research team (K.L.J.C.) calculated the total time spent in bed (TIB; the amount of time from bedtime to rise time) and sleep efficiency (total sleep time divided by TIB × 100). Self-reported sleep-quality parameters are presented as an average of the 7 nights.

The PSQI provided a global score of sleep quality in reference to the past 4 weeks, whereby higher scores indicate worse sleep quality.[25–27] Importantly, the PSQI was not the primary outcome of interest but rather was used to classify individuals as good sleepers (PSQI ≤ 5) and poor sleepers (PSQI > 5).[25] The PSQI contains seven components of sleep including self-reported sleep quality, total duration of sleep, sleep onset latency, habitual sleep efficiency, use of sleeping medications, and the impact of poor sleep on daily functioning.

Device-measured sleep quality

Device-measured sleep quality was assessed using home-based accelerometry, whereby participants wore an ActiGraph GT3×+ device (ActiGraph Corp., Pensecola, FL) on the nondominant wrist during sleeping hours for 7 consecutive nights. Sleep parameters included total TIB (ie, time elapsed between participant logged lights off and lights on), sleep onset latency (ie, lights out to sleep onset), number of awakenings, total sleep time, and sleep efficiency (ie, total sleep time/total time in bed × 100). Raw data were processed with the ActiLife software using the Sleep Features Upgrade as band-pass-filtered and the vector magnitudes of the *x*, *y*, and *z* axes, which were digitally integrated and reported as a single "count" across 60-second epochs. Sleep intervals were defined using a wear time log, where the participant logged lights off time and lights on time. The Cole-Kripke algorithm was applied to determine total sleep time (ie, total number of minutes categorized as "sleep") and sleep efficiency (ie, percentage of time in bed that was scored as sleep).[28] Device-measured sleep quality parameters are presented as an average of the 7 nights.

Demographic and clinical characteristics

Participants completed a questionnaire for demographic and clinical characteristics including items for age, sex, race, marital status, parental status, employment status, education level, income level, MS type, and disease duration. Participants

further reported current medications, including MS related disease-modifying treatments and underwent a physical examination for scoring the Expanded Disability Status Scale as a measure of neurologic disability, whereby higher scores are indicative of greater disability.[29]

Procedure

The university's Institutional Review Board approved all study procedures and participants provided written informed consent. Participants came to the laboratory for a single testing session at baseline, wherein a neurostatus-certified researcher performed a physical examination for scoring the Expanded Disability Status Scale and participants completed the battery of questionnaires. Participants were provided with the accelerometer and instructions for wearing the monitor for 7 full nights along with a wear-time log and the 7-day diary to be completed over the same 7-day period. Participants in the intervention study were provided a prestamped, preaddressed envelope for return service through the United States Postal Service and participants in the cross-sectional study returned the device, log, and diary at an in-person visit the following week. All sessions were administered by the same assessor and participants were remunerated $25 upon the completion of each session.

Statistical analyses

All data were analyzed in SPSS Statistics, Version 26 (IBM Corporation, Armonk, NY), and descriptive statistics are reported as mean and standard deviation (SD), unless otherwise noted. We examined frequency distributions and conducted Shapiro-Wilks analysis for establishing normality of the variables, whereby a P value of > .05 was indicative of a normal distribution. We examined differences in demographic and clinical characteristics as well as in self-reported and device-measured sleep parameters between study subsamples and between sleep disorder groups (ie, MS + RLS group and MS-only group). Differences were examined with independent samples t tests for normally distributed continuous variables and Mann-Whitney U tests for nonnormally distributed continuous variables, whereby an a priori alpha level of 0.05 indicated a significant difference. There were no significant differences between study subsamples or sleep disorder groups (**Table S1**, **Table S2**, and **Table S3** in the supplemental material); therefore, subsamples were combined into a single sample for further analyses. As motor disability is an important correlate of sleep quality in MS,[30] we further analyzed the bivariate nonparametric correlations between Expanded Disability Status Scale scores and parameters of sleep, and there were no significant correlations (**Table S4** in the supplemental material).

We examined the mean difference between self-reported and device-measured sleep parameters using one-sample Wilcoxon signed-rank sum tests on variables not normally distributed and one-sample t tests on variables normally distributed. We assessed intraclass correlation coefficient (ICC) estimates and 95% confidence intervals based on average measures, absolute agreement, 2-way mixed-effects models whereby ICC (r) values of .75 and .90 were thresholds indicative of good and excellent reliability, respectively.[31] We examined the agreement between the two methods using Bland-Altman plots, as these plots represent the difference between self-reported and device-measured sleep parameters against the mean of the two values, with the solid line representing the mean difference and the dotted line representing the 95% confidence interval (mean difference ± 1.96 SD of mean difference).[32,33] We further conducted linear regression analyses for examining the proportional bias of each outcome, whereby we included the difference between the two methods as the dependent variable and the mean of the two methods as the independent variable in the model.

RESULTS

Participants

The summary of participant demographic and clinical characteristics for the overall sample (n = 49) is presented in **Table 1**. The sample had an average (SD) age of 52.2 (11.3) and was primarily White (65%), female (80%), and married (60%) with 1 or more children (86%). The sample was mostly unemployed (57%) with at least some college or more (82%) and reported an annual household income of $40,000 or more (69%). Regarding clinical characteristics, the sample primarily had relapsing-remitting MS (78%) with an average (SD) disease duration of 15.5 (8.3) years and a median Expanded Disability Status Scale score of 4.0 (interquartile range = 1.0), and 71% of participants reported taking a disease-modifying treatment. Regarding sleep quality, the sample had an average (SD) PSQI global score of 9.7 (3.8) with 84% (n = 41) of people classified as poor sleepers (PSQI > 5).[25] Based on component 6 of the PSQI, 47% of the sample reported using sleeping medications 3 or more times a week on average and 45% reported not using sleep medications over the previous month. Additionally, 33% of the sample with MS and RLS were taking a medication that can be used to manage symptoms of RLS (**Table S1**).

Agreement between self-report and device-measured sleep

The summary of agreement between self-reported and device-measured parameters of sleep characteristics in the overall sample (n = 49) is presented in **Table 2**. Participants self-reported less TIB (mean difference =19.8 [51.3] minutes), longer sleep latency (mean difference = 22.2 [19.5] minutes), fewer awakenings during the night (mean difference = 12.8 [6.8]), shorter sleep duration (mean difference = 19.9 [71.8] minutes), and similar sleep efficiency compared with device-measured values. The magnitude of difference between the two methods significantly deviated from the hypothesized value of 0 (ie, no difference between estimates) for total TIB (P = .002), sleep onset latency (P < .001), and number of awakenings (P < .001). Based on ICC estimates, only TIB demonstrated acceptable agreement between methods (ICC = 0.80).

Bland-Altman plots for illustrating the agreement between self-reported and device-measured sleep parameters are presented in **Figure 1**. Linear regression analyses indicated that parameters of sleep onset latency (F = 113.91, B = −1.34,

Table 1—Participant demographic and clinical characteristics for the overall sample of persons with multiple sclerosis.

	Overall Sample (n = 49)
Age, y	52.2 (11.3)
Sex (female/male)	39 (80%)/10 (20%)
Race	
White	32 (65%)
Black/African American	16 (33%)
Latino/Latina	1 (2%)
Marital status, n (%)	
Married	29 (60%)
Single	20 (40%)
Parental status, n (%)	
No children	7 (14%)
1+ children	42 (86%)
Employment status, n (%)	
Employed	21 (43%)
Unemployed	28 (57%)
Educational level, n (%)	
No college or less	9 (18%)
Some college or more	40 (82%)
Income, n (%)	
<$40,000/y	13 (27%)
≥$40,000/y	34 (69%)
MS type, n (%)	
RRMS	38 (78%)
PPMS/SPMS	11 (22%)
Disease duration, y	15.5 (8.3)
EDSS step (median [IQR])	4.0 [1.0]
Currently taking DMT, n (%)	35 (71%)
PSQI global score	9.7 (3.8)
Poor sleeper status, n (%)	41 (84%)
Use of sleeping medication, n (%)	
Not during past month	22 (45%)
< 1 time/wk	0 (0%)
1–2 times/wk	4 (8%)
3+ times/wk	23 (47%)

Values are means (standard deviations) unless otherwise noted. Use of sleeping medication is based on component 6 of the Pittsburgh Sleep Quality Index. DMT = disease-modifying treatment, IQR = interquartile range, EDSS = Expanded Disability Status Scale, MS = multiple sclerosis, PPMS/SPMS = primary progressive MS/secondary progressive MS, PSQI = Pittsburgh Sleep Quality Index, RRMS = relapsing-remitting MS.

$P < .001$), number of awakenings ($F = 543.34$, B = 1.85, $P < .001$), and sleep efficiency ($F = 18.39$, B = −0.77, $P < .001$) had significant proportional bias. The difference between methods for sleep onset latency and sleep efficiency decreased in proportion to the average of the two methods, whereas the difference in number of awakenings increased in proportion to the average of the two methods.

DISCUSSION

The present study examined the agreement between self-reported (ie, sleep diary) and device-measured (ie, actigraphy) parameters of sleep quality in a sample of adults with MS. Our primary findings suggest that (1) there was a significant discrepancy between self-reported and device-measured TIB, sleep onset latency, and frequency of awakenings during the night; (2) ICC estimates indicated poor agreement between methods on most parameters, except for total TIB; and (3) Bland-Altman plots suggested that TIB and total sleep time had acceptable levels of agreement. As sleep discrepancies are common in adults with MS[3,34] and can negatively influence other symptoms and consequences of MS,[3–5] it is becoming increasingly important to accurately quantify sleep parameters in this population. Our results suggest that there may be discrepancies between self-reported and device-measured sleep parameters in adults with MS, and researchers and clinicians should utilize both self-reported and device-measured outcomes when quantifying sleep in adults with MS.

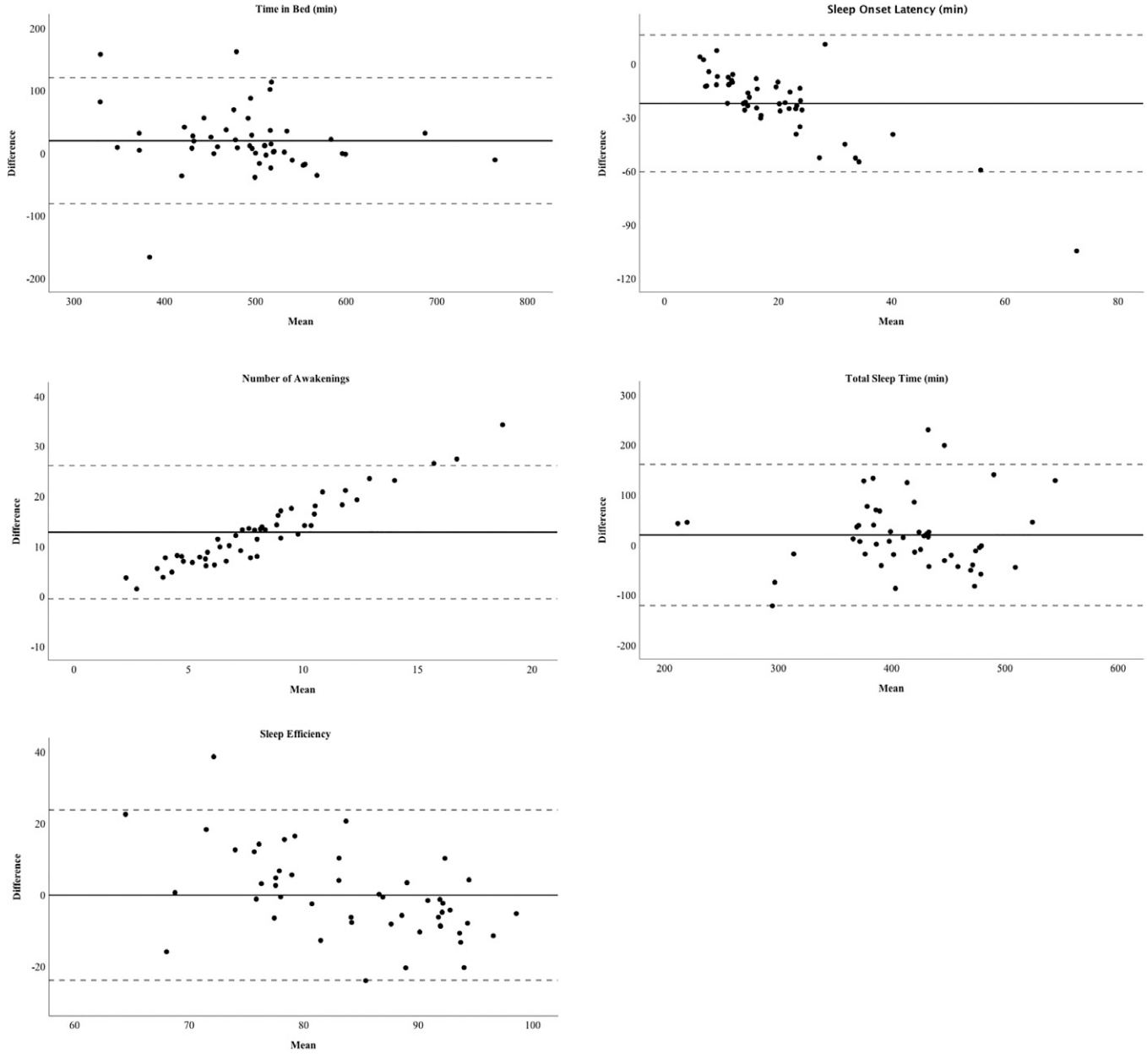
Our results suggested that there may be significant discrepancies between self-reported and device-measured sleep parameters in adults with MS. Although our sample self-reported significantly less total TIB (mean difference = 19.8 [51.3] minutes) compared with device-measured TIB, the ICC estimate and Bland-Altman plot for examining the agreement between the two methods for total TIB indicated that there was acceptable agreement between methods. This pattern of results suggests that the discrepancy is likely uniform across people such that there is an absolute difference, but the rank ordering or consistency of scores across participants from the two outcome measures is similar between measures—this latter observation would explain the acceptable ICC and agreement. A recent study demonstrated comparable parameters of total TIB between a sleep diary and the ActiGraph GT3×+ averaged over 3 nights in otherwise healthy adults.[14] The acceptable agreement for TIB may be because of methodological similarities between the 2 methods, as processing raw data from the ActiGraph GT3×+ requires participant logged time-on (ie, lights off) and time-off (ie, lights on), whereby participants may report the time-on as the bedtime and time-off as the waketime (or vice versa), which are used to calculate TIB for both methods. However, the significant difference of approximately 20 minutes between methods is perplexing considering both logs requested lights-off time for the time in bed and lights-on time for the time out of bed. This suggests that participants put on the monitor before the intent to go to sleep at night and/or took off the monitor later than they actually awoke for the day. On the other hand, the mean difference between methods for total sleep time were statistically similar (mean difference = 19.9 [71.8] minutes) and the Bland-Altman plot suggested acceptable agreement between the two methods; however, the ICC estimate suggests poor agreement between the two methods. Acceptable agreement for total sleep time is consistent with previous literature in otherwise healthy adults,[13–15] women with fibromyalgia,[16,17] and in patients with chronic low back pain.[18] Collectively, self-reported total TIB and total sleep duration may be comparable to device-measured parameters.

Table 2—Self-reported and device-measured sleep parameters in sample of persons with multiple sclerosis (n = 49).

Sleep-Quality Parameter	Self-Reported	Device-Measured	Mean	Mean (SD) Difference	*P*	ICC
Total TIB, min	481.8 (88.3)	501.6 (80.6)	491.7 (80.6)	−19.8 (51.3)	.002+	0.797
Sleep onset latency, min	30.7 (21.1)	8.5 (6.6)	19.6 (12.2)	22.2 (19.5)	<.001+	0.111
Number of awakenings	1.8 (1.0)	14.6 (6.9)	8.2 (3.5)	−12.8 (6.8)	<.001+	0.009
Total sleep time, min	401.7 (73.7)	421.6 (77.2)	411.6 (66.3)	−19.9 (71.8)	.145+	0.533
Sleep efficiency, %	84.2 (12.7)	84.1 (7.3)	84.2 (8.4)	0.1 (12.1)	.602#	0.320

Values are means (SD). +One-sample Wilcoxon signed-rank test. #One-sample *t* test. ICC = intraclass correlation coefficient based on two-way mixed-effects, absolute-agreement, single-measures models, SD = standard deviation, TIB = time in bed.

Figure 1—Bland-Altman plots for illustrating the agreement between self-reported and device-measured sleep parameters in adults with multiple sclerosis (n = 49).



In our sample of adults with MS, participants self-reported similar sleep efficiency to device-measured estimates; however, ICC estimates and the Bland-Altman plot suggested poor agreement, whereby there was significant proportional bias between the 2 methods. Thus, the difference between methods decreased in proportion to the average of the 2 methods. These results are similar to a previous study that demonstrated a significant association between self-reported and device-measured sleep efficiency for healthy adults but no significant association between the 2 methods in patients with chronic low back pain.[18] The conflicting outcomes of agreement may derive from the agreement metrics of total TIB and sleep duration, as sleep efficiency is calculated by dividing total sleep time by total TIB and then multiplying by 100. Of note, our results suggest acceptable agreement for TIB based on ICC estimates and Bland-Altman examination and acceptable agreement for total sleep time based on the Bland-Altman plot. Thus, variability in parameters of TIB and sleep duration would influence sleep efficiency, whereby the significant difference between measurement methods for TIB and the poor agreement between methods based on ICC estimates for total sleep time may influence the agreement for sleep efficiency. However, this discrepancy requires additional exploration in larger samples of adults with MS.

There were significant discrepancies between methods for sleep onset latency and number of awakenings, whereby participants self-reported longer sleep onset latency (mean difference = 22.2 [19.5] minutes) and fewer awakenings during the night (mean difference = 12.8 [6.8]) compared to device-measured parameters. Further, ICC estimates and Bland-Altman plots for sleep onset latency and frequency of awakenings indicated that there was poor agreement between the 2 methods for these parameters, which is similar to previous findings in patients with chronic low back pain[18] and women with fibromyalgia.[16] These discrepancies may be due to the conscious awareness required of accurately reporting these parameters, as self-reporting the amount of time it takes to fall asleep or the number of times a person awoke during the night requires the awareness of time, which most people are not concentrating on when asleep. Further, actigraphy may capture awakenings that are brief and not often recognized by the participant. On the other hand, actigraphy relies on movement to measure these parameters and may underestimate sleep onset latency due to the lack of movement when trying to fall asleep.[35] Collectively, our results draw attention to the discrepancies that can occur with only one type of measurement outcome and highlight the importance of including both self-report and device-measured outcomes for a complete and accurate representation of sleep in adults with MS.

There are important limitations to consider when interpreting our results. The sample was primarily White (65%) with relapsing-remitting MS (78%), suggesting that our sample may not be fully representative of the MS population. Combining two samples with different sets of inclusion criteria may influence the results of this study. Although sleep disorders are common in adults with MS,[34] our sample included a relatively large number of participants with RLS (n = 29, 59%), which is higher than the expected prevalence of approximately 20% in this population.[36] The high rate of participants with RLS may be an explanation for the high percentage of participants classifying as poor sleepers (84%), which is higher than previously reported in adults with MS,[3,37,38] and almost half of our sample was using sleeping medications 3 or more days out of the week. The device-measured sleep parameter of TIB, and therefore sleep efficiency, was dependent on self-logged lights-off and lights-on time. Future research should utilize a device or algorithm that can estimate lights-off and lights-on time more accurately.

CONCLUSIONS

The present study examined the agreement between self-reported and device-measured sleep parameters in a sample of adults with MS. Our primary results suggest that there may be acceptable agreement between self-reported and device-measured total TIB and total sleep time but not for sleep onset latency, number of awakenings, or sleep efficiency. These results further highlight the importance of utilizing both self-report and device-measured outcomes of sleep to capture all aspects of sleep quality in adults with MS. Future research should further evaluate the agreement between self-report and objectively measured parameters of sleep, including the use of actigraphy and polysomnography, in a larger sample of adults with MS with and without sleep disorders.

ABBREVIATIONS

ICC, intraclass correlation coefficient
MS, multiple sclerosis
PSQI, Pittsburgh Sleep Quality Index
RLS, restless legs syndrome
SD, standard deviation
TIB, time in bed

REFERENCES

1. Wallin MT, Culpepper WJ, Campbell JD, et al; US Multiple Sclerosis Prevalence Workgroup. The prevalence of MS in the United States: a population-based estimate using health claims data. *Neurology.* 2019;92(10):e1029–e1040.
2. Multiple Sclerosis International Federation. Atlas of MS: Mapping Multiple Sclerosis Around the World. https://www.atlasofms.org/map/global/epidemiology/number-of-people-with-ms. Accessed September 24, 2020.
3. Sakkas GK, Giannaki CD, Karatzaferi C, Manconi M. Sleep abnormalities in multiple sclerosis. *Curr Treat Options Neurol.* 2019;21(1):4.
4. Buratti L, Iacobucci DE, Viticchi G, et al. Sleep quality can influence the outcome of patients with multiple sclerosis. *Sleep Med.* 2019;58:56–60.
5. Ghaem H, Borhani Haghighi A. The impact of disability, fatigue and sleep quality on the quality of life in multiple sclerosis. *Ann Indian Acad Neurol.* 2008;11(4):236–241.
6. Tamaki M, Nittono H, Hayashi M, Hori T. Examination of the first-night effect during the sleep-onset period. *Sleep.* 2005;28(2):195–202.
7. Curcio G, Ferrara M, Piergianni A, Fratello F, De Gennaro L. Paradoxes of the first-night effect: a quantitative analysis of antero-posterior EEG topography. *Clin Neurophysiol.* 2004;115(5):1178–1188.
8. Agnew HW Jr, Webb WB, Williams RL. The first night effect: an EEG study of sleep. *Psychophysiology.* 1966;2(3):263–266.
9. Devine EB, Hakim Z, Green J. A systematic review of patient-reported outcome instruments measuring sleep dysfunction in adults. *Pharmacoeconomics.* 2005;23(9):889–912.

10. Malasinghe LP, Ramzan N, Dahal K. Remote patient monitoring: a comprehensive study. *J Ambient Intell Humaniz Comput.* 2019;10(1):57–76.
11. Vegesna A, Tran M, Angelaccio M, Arcona S. Remote patient monitoring via non-invasive digital technologies: a systematic review. *Telemed J E Health.* 2017; 23(1):3–17.
12. Walia HK, Mehra R. Practical aspects of actigraphy and approaches in clinical and research domains. *Handb Clin Neurol.* 2019;160:371–379.
13. Jackowska M, Ronaldson A, Brown J, Steptoe A. Biological and psychological correlates of self-reported and objective sleep measures. *J Psychosom Res.* 2016; 84:52–55.
14. Lee JM, Byun W, Keill A, Dinkel D, Seo Y. Comparison of wearable trackers' ability to estimate sleep. *Int J Environ Res Public Health.* 2018;15 (6):E1265.
15. St-Onge MP, Campbell A, Salazar I, Pizinger T, Liao M, Aggarwal B. Information on bedtimes and wake times improves the relation between self-reported and objective assessments of sleep in adults. *J Clin Sleep Med.* 2019;15(7):1031–1036.
16. Segura-Jiménez V, Camiletti-Moirón D, Munguía-Izquierdo D, et al. Agreement between self-reported sleep patterns and actigraphy in fibromyalgia and healthy women. *Clin Exp Rheumatol.* 2015;33(suppl 88):S58–S67.
17. Landis CA, Frey CA, Lentz MJ, Rothermel J, Buchwald D, Shaver JL. Self-reported sleep quality and fatigue correlates with actigraphy in midlife women with fibromyalgia. *Nurs Res.* 2003;52(3):140–147.
18. O'Donoghue GM, Fox N, Heneghan C, Hurley DA. Objective and subjective assessment of sleep in chronic low back pain patients compared with healthy age and gender matched controls: a pilot study. *BMC Musculoskelet Disord.* 2009; 10(1):122.
19. Sadeghi Bahmani D, Gonzenbach R, Motl RW, et al. Better objective sleep was associated with better subjective sleep and physical activity; results from an exploratory study under naturalistic conditions among persons with multiple sclerosis. *Int J Environ Res Public Health.* 2020;17(10):E3522.
20. Cederberg KLJ, Walters AS, Amara AW, et al. Validity and reliability of the suggested immobilization test for measurement of restless legs syndrome severity in adults with multiple sclerosis. *Sleep Med.* 2021;84:343–351.
21. Allen RP, Burchell BJ, MacDonald B, Hening WA, Earley CJ. Validation of the self-completed Cambridge-Hopkins questionnaire (CH-RLSq) for ascertainment of restless legs syndrome (RLS) in a population survey. *Sleep Med.* 2009;10(10): 1097–1100.
22. Marrie RA, Goldman M. Validity of performance scales for disability assessment in multiple sclerosis. *Mult Scler.* 2007;13(9):1176–1182.
23. Cederberg KLJ, Motl RW. Feasibility and efficacy of a physical activity intervention for managing restless legs syndrome in multiple sclerosis: results of a pilot randomized controlled trial. *Mult Scler Relat Disord.* 2021;50: 102836.
24. Carney CE, Buysse DJ, Ancoli-Israel S, et al. The consensus sleep diary: standardizing prospective sleep self-monitoring. *Sleep.* 2012;35(2):287–302.
25. Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res.* 1989;28(2):193–213.
26. Backhaus J, Junghanns K, Broocks A, Riemann D, Hohagen F. Test-retest reliability and validity of the Pittsburgh Sleep Quality Index in primary insomnia. *J Psychosom Res.* 2002;53(3):737–740.
27. Carpenter JS, Andrykowski MA. Psychometric evaluation of the Pittsburgh Sleep Quality Index. *J Psychosom Res.* 1998;45(1):5–13.
28. Cole RJ, Kripke DF, Gruen W, Mullaney DJ, Gillin JC. Automatic sleep/wake identification from wrist activity. *Sleep.* 1992;15(5):461–469.
29. Kurtzke JF. Rating neurologic impairment in multiple sclerosis: an expanded disability status scale (EDSS). *Neurology.* 1983;33(11):1444–1452.
30. Monschein T, Schestak C, Schillerwein-Kral C, et al. Restless legs syndrome in multiple sclerosis: risk factors and effect on sleep quality - a case-control study. *Mult Scler Relat Disord.* 2021;51:102916.
31. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J Chiropr Med.* 2016;15(2):155–163.
32. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet.* 1986;1(8476):307–310.
33. Giavarina D. Understanding Bland Altman analysis. *Biochem Med (Zagreb).* 2015; 25(2):141–151.
34. Braley TJ, Boudreau EA. Sleep disorders in multiple sclerosis. *Curr Neurol Neurosci Rep.* 2016;16(5):50.
35. Lichstein KL, Stone KC, Donaldson J, et al. Actigraphy validation with insomnia. *Sleep.* 2006;29(2):232–239.
36. Ning P, Hu F, Yang B, et al. Systematic review and meta-analysis of observational studies to understand the prevalence of restless legs syndrome in multiple sclerosis: an update. *Sleep Med.* 2018;50:97–104.
37. Siengsukon CF, Alshehri M, Aldughmi M. Self-report sleep quality combined with sleep time variability distinguishes differences in fatigue, anxiety, and depression in individuals with multiple sclerosis: a secondary analysis. *Mult Scler J Exp Transl Clin.* 2018;4(4):2055217318815924.
38. Vitkova M, Rosenberger J, Gdovinova Z, et al. Poor sleep quality in patients with multiple sclerosis: gender differences. *Brain Behav.* 2016;6(11):e00553.

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