Refining sleep measurement using the Motionwatch8©: How many days of monitoring do we need to get reliable estimates of sleep quality for older adults with Mild Cognitive Impairment?

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Abstract

Background

Mild cognitive impairment (MCI) is a transition stage between healthy cognition and dementia, and is linked to poorer sleep. Objective, reliable, and low-burden field methods to measure older adult sleep are also currently needed. The MotionWatch8© (MW8) wrist-worn actigraph provides estimates of sleep with 14 days of observation; however, there may be underlying differences in the reliability of sleep estimates based on MCI status. We therefore investigated the number of MW8 monitoring days required to estimate sleep in older adults with MCI and without.

Methods

Older adults (55+ years; N=151) wore the MW8 for ≥14 days. The Montreal Cognitive Assessment was used to categorize participants with probable MCI (scores of <26/30) and participants without MCI (≥26/30). We calculated intra-class reliability coefficients for 1-, 7-, and 14-days of wear-time, and performed Spearman-Brown predictions to determine the number of monitoring days needed for an ICC=0.80.

Results

Older adults with MCI were older (p<0.01), more likely to be male (p=0.03), and had shorter sleep duration (p<0.01). Spearman-Brown analyses indicated that the number of monitoring days needed for an ICC=0.80 in older adults with probable MCI was 7 days for sleep duration, 4 days for fragmentation, and 4 days for efficiency; adults without MCI required 4 days for duration, 6 days for fragmentation, and 3 days for efficiency.

Conclusions

Our results indicate that while the reliability of MW8 estimates of sleep differs based on cognitive status, 7 days of MW8 monitoring provides reliable estimates of sleep for adults with MCI and those without.

Background

Promoting older adult cognitive health is a public health priority since the number of older adults with cognitive impairment and dementia is increasing (1). Lifestyle and behavioural modification strategies which promote or maintain cognitive health are thus a frontline, low-cost, and increasingly popular line of research inquiry.

Good sleep is critical for healthy aging. Sleep can be measured objectively using polysomnography (the gold standard for measuring sleep quality) or estimated using wrist-worn and hip-worn actigraphy; sleep can also be measured subjectively by questionnaire. Sleep changes as a function of normal aging both in terms of decreased quality and quantity (2, 3), however more than half of adults over 65 years of age

report at least one chronic sleep complaint—the most common being the inability to stay asleep at night (4). One reason is age-associated changes in the sleep-wake cycle of older adults (2, 5). For example, homeostatic drive (i.e., Process S) declines with age (6). Older adults also commonly report excessive daytime sleepiness—which is a key indicator of accumulated sleep debt (3).

While changes in sleep are likely an unavoidable consequence of aging (2, 7, 8), older adults who sleep poorly are at increased risk for mild cognitive impairment (MCI) and dementia (9). MCI is a transition period between healthy cognitive aging and dementia, and is thus a critical time to intervene to promote cognitive health (10). MCI is defined as cognitive decline greater than expected for age and education level which does not interfere with independence (11). An estimated 10–20% of adults over 65 years of age are living with MCI (12), which is associated with up to a 30% increased risk of developing dementia within 5 years (13). Importantly, older adults with MCI are more likely to experience poor sleep than healthy older adults (14), and poor sleep is associated with an increased risk of progression from MCI to dementia (15). Animal models indicate that chronic poor sleep leads to increased cortical amyloid-beta (Aβ)—a hallmark pathology of Alzheimer's disease (16). Sleep deprivation of rodents also escalates Aβ production (17), while sleep promotes the clearance of Aβ (18). Sleep is thus a critical pathway by which the brain appears to maintain cognitive health. When this pathway is disrupted, a vicious cycle of accelerating cognitive decline may occur—whereby poor sleep may lead to increasing cognitive decline, and vice-versa (19).

Valid and reliable field methods for measuring sleep are thus needed to understand the impact of sleep on cognitive health. The gold standard for measuring sleep is polysomnography (20); however the invasive nature of polysomnography—usually requiring an overnight stay in a sleep laboratory or clinic—makes long-term multi-night recordings impractical. Subjective measures of sleep are quick and easy to administer and score, and can discriminate "good" vs. "poor" sleepers, but they are not able to detect subtle but clinically important changes in sleep due to age or disease (21). Estimating sleep using actigraphy is therefore an increasingly popular alternative for measuring sleep, although it is open to issues of validity and reliability compared to polysomnography (20). Nonetheless, actigraphy does provide an objective method of estimating sleep in a natural environment which can span multiple nights, thus delivering a clearer illustration of an older adult's usual sleep.

One readily-available actigraph capable of measuring sleep quality is the Motionwatch8© wrist-worn accelerometer (MW8; 22). Previous investigations with the device have observed sleep quality over a period of 14 days (21, 23), since this measurement protocol is based on current guidelines and past analyses of actigraphy (24, 25); however, reducing the number of days necessary to wear the MW8 could reduce participant burden. Moreover, since older adults with MCI appear to have different sleep than their healthy cognitive counterparts (14, 15), it is plausible that the MW8 may have different estimates of reliability for the measurement of sleep based on cognitive status. Hence, we examined the necessary number of days for obtaining reliable estimates of older adult sleep in older adults with MCI and those without.

Methods

Ethical approval for this study was obtained from the Vancouver Coastal Health Research Institute and the University of British Columbia's Clinical Research Ethics Board (H14-01301). All participants provided written informed consent.

Participants

Data for this study were collected as part of the Sleep and Cognition Study, a cross-sectional study examining the associations between sleep quality and cognition among older adults (26). We recruited and collected data between August 27, 2014 and June 30, 2016. Details of the full study protocol can be found elsewhere (26). We recruited 153 older adults from Vancouver, British Columbia by advertisements placed in local community centres, newspapers, and word of mouth referrals. Interested individuals were initially pre-screened for eligibility criteria.

Participants were included if they: 1) were 55+ years of age living the Greater Vancouver area; 2) scored ≥24/30 on the Mini-Mental State Examination (MMSE; [27]), with scoring of attention being performed using serial sevens; and 3) were able to read, write, and speak English with acceptable visual and auditory acuity. Participants were excluded if they were: 1) diagnosed with dementia of any type; 2) diagnosed with another type of neurodegenerative or neurological condition; 3) taking medications that may negatively affect cognitive function; 4) planning to participate or were currently enrolled in a clinical drug trial; or 5) unable to speak as judged by an inability to communicate by phone. Individuals were not excluded based on use of medications which may affect sleep quality (either negatively or positively), nor were participants selected on the basis of their sleep.

Study Design and Measurement

At study entry, we ascertained general health, subjective sleep quality using the Pittsburgh Sleep Quality Index (PSQI; [28]), height to the nearest 0.1 cm using a stadiometer, weight to the nearest 0.1 kg using an electronic scale, demographics, socioeconomic status, and education by a questionnaire. Height and weight were used to calculate body mass index (BMI; kg/m^2; [29]). Global cognitive function was assessed by the MMSE (27), and the Montreal Cognitive Assessment (MoCA; [30]). We categorized participants based on MCI status with a score of <26/30 on the MoCA indicating probable MCI, which has been found to have good internal consistency and test-retest reliability, and was able to correctly identify 90% of a large sample of MCI individuals from two different clinics (30).

Participants were then fitted with the MW8 and provided detailed information on its features (i.e., the light sensor, event marker button, and status indicator). Participants were instructed to press the event marker button each night when they started trying to sleep; and again each morning when they finished trying to sleep. Consistent with established protocol for wrist-worn actigraphy, participants wore the MW8 on the non-dominant wrist (24, 31).

Participants were also given the 9-item Consensus Sleep Diary (CSD; [32]) and asked to complete it each morning upon waking. The responses from the CSD were used to confirm sleep windows as determined by the time stamped event markers. In cases where the event marker and CSD entry disagreed for the start time of the sleep window, we used activity cessation and light sensor data from the MW8 to determine “lights out”. Similarly, when the event marker and CSD entry disagreed for the end of the sleep window, we used activity onset and “lights on” to determine the end of the sleep window. If responses from the CSD entry disagreed with the event markers entered by participants as the start of the day (i.e., finished trying to sleep and awake and out of bed), we used activity onset and light sensor data to determine the start of the day. Similarly, when the event marker and CSD entry disagreed for the end of day (i.e., time spent trying to sleep), we used activity cessation and light sensor data to determine the end of the day. In accordance with the currently established protocol for measuring sleep quality via actigraphy (24, 31), each participant was continuously monitored for a minimum of 14 nights. After collection, stored activity counts were downloaded and saved to an IBM compatible computer for subsequent data reduction and analysis.

MW8 Instrumentation and Data Reduction

We measured sleep using the MW8 actigraphy system (CamNtech; Cambridge, United Kingdom). The MW8 is a tri-axial accelerometer designed to observe acceleration ranging in magnitude from 0.01G to 8G, with a frequency of 3-11Hz. The filtered acceleration signal is digitized and the magnitude is summed over a user-specified time interval. At the end of each interval, the summed value or activity “count” is stored in memory and the integrator is reset. The MW8 is the updated version of the Actiwatch7, an actigraph with evidence of validity against polysomnography in healthy adults (Mean age: 30 ± 6 years; 45% female; [33]), and also adults with chronic insomnia (Mean age: 41 ± 12 years; 78% female; [34]). There is also initial evidence of validity against polysomnography for the MW8 among 1) 54 adults with suspected sleep disorders including obstructive sleep apnea, insomnia, hypersomnia, and Ehlers Danlos syndrome (Mean Age: 53 ± 16 years; 61% female); and 2) 19 healthy adults (Mean Age: 28 ± 5 years; 53% female; [35]). For the current study, we used 60 second epochs (24, 31).

Data were analyzed using MotionWare 1.0.27 (cam*n*tech) to estimate different sleep indices including: *fragmentation index*, *sleep efficiency* (time asleep expressed as a percentage of time in bed), *sleep duration* (total time spent sleeping), *sleep latency* (time between “lights out” and falling asleep), and *wake after sleep onset* (time spent awake after sleep has been initiated and before final awakening). Fragmentation index is a description of restlessness while sleeping and is defined by MotionWare as the sum of 1) the total time spent sleeping categorized as *mobile* in the epoch-by-epoch *mobile/immobile* categorization expressed as a percentage of the time spent asleep; and 2) the number of *immobile* bouts which were equal to 1 minute in length expressed as a percentage of the total number of *immobile* bouts during time spent sleeping. Only minutes categorized as asleep were included in the calculation of fragmentation index.

Statistical Analyses

We performed all of our statistical analyses using R version 3.3.1 using the *psych, Hmisc*, and *ICC* packages. Our statistical code can be found in Supplementary Material S1. Two participants did not complete the MoCA. These individuals were removed from analyses such that our final sample was 151 participants.

Participant characteristics based on probable MCI status

We calculated means and standard deviations for all variables of interest based upon probable MCI status (i.e., MoCA score <26/30). We determined demographic differences in probable MCI status using independent sample *t*-tests for continuous variables and chi-square tests for categorical variables, using probable MCI status (yes/no) as the grouping variable. Subsequently, we performed analyses of covariance (ANCOVA) to determine differences in estimates of sleep quality based on probable MCI status. We performed separate ANCOVA models for each of our measures estimating sleep quality (i.e., PSQI total score, PSQI sleep duration, and MW8 measured sleep duration, fragmentation index, sleep efficiency, sleep latency, and wake after sleep onset), wherein we controlled for age, sex, and sleep medication use while using probable MCI status as the grouping variable.

Reliability of the MW8 for estimating sleep quality based on probable MCI status

We then calculated between-day intraclass correlations (ICC) and 95% confidence intervals (CI) for 1, 4, 7 and 14 days of monitoring, and classified ICCs according to the criteria of Koo and Li (36). For single day ICC's we used a single absolute intraclass correlation coefficient ($ICC_{1,1}$) to determine single day expected reliability using the following formula (37):

$$\frac{BMS - EMS}{BMS\,(k-1)EMS + k(\frac{TMS - EMS}{N})}$$

Wherein, *BMS* is the between subject mean square, the *EMS* is the residual error, *TMS* is the trial mean square, *k* refers to the number of trials (in this case, one trial), and *N* is the number of participants. We used all 14 days of data to calculate our single day ICCs. For our analysis of multiple day reliability, we used average random raters ($ICC_{2,k}$) using the same formula, wherein *k* was the number of days monitored. For our calculations of 4 and 7 day reliability, we only used data from the first 4 and 7 days, respectively.

We also calculated the required days of monitoring needed to achieve ICC's of 0.70, 0.80 and 0.90 using the Spearman-Brown prophecy formula (38). Subsequently, we calculated separate ICCs and Spearman-Brown prophecies for 1) participants with probable MCI and 2) those without MCI. We then performed *z* tests to determine if ICC estimates for our different sleep parameters differed significantly by MCI status after 1, 4, 7, and 14 days of monitoring.

Results

Participant Characteristics Based on Probable MCI Status

Participant characteristics are described in Table 1. Mean participant age was 71.19 years (SD= 7.26; Range: 55-101 years), 66.89% of the sample was female, and 77.48% were retired. Average BMI was 26.71 kg/m^2 (SD= 5.05; Range: 17.08-42.40 kg/m^2), 13.25% of the sample used sleep medications, and average MMSE score was 28.89 (SD= 1.11; Range: 25-30). Average PSQI score was 7.28 (SD= 4.00; Range: 1-18), and participants reported sleeping an average of 373.60 minutes/day (SD= 73.43; Range: 120-570 minutes/day) on the PSQI. Participants had an average MW8 measured sleep duration of 401.10 minutes/day (SD= 51.23; Range: 164.85-541.77 minutes/day), average fragmentation index of 31.17 (SD= 11.03; Range: 11.21-57.15), and average sleep efficiency of 82.57% (SD= 6.10; Range: 66.74-94.99%).

Older adults with probable MCI were significantly older (p= 0.01), more likely to be male (p= 0.03), and had poorer performance on the MMSE (p< 0.01). Older adults with probable MCI had significantly shorter subjective sleep duration on the PSQI (p= 0.01) and shorter MW8 measured sleep duration (p< 0.01) than their healthy cognitive peers after controlling for age, sex, and sleep medication use.

Reliability Coefficients

All participants (N= 151)

Intraclass reliability coefficients and 95% CI for mean daily activity levels derived from 1, 4, 7 and 14 days are shown in Table 2. The reliability coefficients exhibit a trend towards greater reliability for sleep duration, fragmentation index, sleep efficiency, and wake after sleep onset. Overall, there was poor reliability of sleep quality indices derived from a single day of monitoring. Wake after sleep onset was the most reliable with an estimate of ICC= 0.64 (95% CI: 0.59, 0.70). Sleep latency showed the least agreement with ICC= 0.33 (95% CI: 0.27, 0.39). Reliability estimates for 7 days showed moderate-to-high reliability across all five sleep quality indices. Sleep duration had a reliability ICC=0.84 (95% CI: 0.80, 0.88) at 7 days, fragmentation index had an ICC= 0.90 (95% CI: 0.87, 0.92), sleep efficiency had an ICC= 0.92 (95% CI: 0.90, 0.94), sleep latency had an ICC= 0.73 (95% CI: 0.66, 0.79), and wake after sleep onset had an ICC= 0.93 (95% CI: 0.91, 0.94). Spearman-Brown analyses indicated that in order to achieve reliability of ICC= 0.80, sleep duration needed to be monitored for 5 days, fragmentation index for 4 days, sleep efficiency for 3 days, sleep latency for 12 days, and wake after sleep onset for 3 days.

Older adults without MCI (N= 69)

There was poor reliability of sleep quality indices derived from a single day of monitoring for adults without MCI. Sleep efficiency was the most reliable with an estimate of ICC= 0.61 (95% CI: 0.53, 0.70), while sleep latency showed the least agreement with ICC= 0.31 (95% CI: 0.23, 0.41). Reliability estimates for 7 days showed moderate-to-high reliability across all five sleep quality indices. Sleep duration had a reliability ICC= 0.86 (95% CI: 0.81, 0.91) at 7 days, fragmentation index had an ICC= 0.85 (95% CI: 0.79, 0.90), sleep efficiency had an ICC= 0.91 (95% CI: 0.87, 0.94), sleep latency had an ICC= 0.73 (95% CI: 0.62, 0.82), and wake after sleep onset had an ICC= 0.91 (95% CI: 0.88, 0.94). In order to achieve reliability of ICC= 0.80, sleep duration needed to be monitored for 4 days, fragmentation index needed to be monitored

for 6 days, sleep efficiency needed 3 days, sleep latency needed 9 days, and wake after sleep onset needed 3 days.

Older adults with probable MCI (N= 82)

We determined there was poor reliability of sleep quality from a single day of monitoring for all sleep quality indices in adults with probable MCI. Wake after sleep onset was the most reliable with an estimate of ICC= 0.68 (95% CI: 0.61, 0.75), while sleep latency showed the least agreement with ICC= 0.35 (95% CI: 0.27, 0.44). Reliability estimates for 7 days showed modest-to-good reliability across all four sleep quality indices. Sleep duration had a reliability ICC= 0.80 (95% CI: 0.73, 0.86) at 7 days, fragmentation index had an ICC= 0.91 (95% CI: 0.88, 0.94), sleep efficiency had an ICC= 0.92 (95% CI: 0.89, 0.95), sleep latency had an ICC= 0.73 (95% CI: 0.63, 0.81), and wake after sleep onset had an ICC= 0.93 (95% CI: 0.91, 0.95). Spearman-Brown prophecies indicated that in order to achieve reliability of ICC= 0.80, sleep duration needed to be monitored for 6 days, fragmentation index and sleep efficiency needed 3 days, sleep latency needed 8 days, and wake after sleep onset needed 2 days.

Differences in ICC estimates for different sleep parameters by cognitive status

Significantly different ICCs are demarcated in Table 2. We determined that there were significantly different ICCs based on cognitive status for fragmentation index following 14 days (z= 2.34; p= 0.02) and 1 day (z= 2.68; p< 0.01) of monitoring. There were marginally different ICCs based on cognitive status for sleep duration following 1 (z= 1.85; p= 0.06) and 4 days (z= 1.96; p= 0.05) of monitoring, sleep fragmentation following 4 (z= 1.89; p= 0.06) and 7 days (z= 1.88; p= 0.06), and wake after sleep onset following 1 (z= 1.78; p= 0.08) and 14 days (z= *1.85;* p= 0.06).

Discussion

Our results indicate the MW8 provides reliable estimates of sleep after at least 7 days of observation for both older adults with MCI and those without. Specifically, we found that at least 7 days of monitoring—irrespective of cognitive status—provides good agreement for sleep duration (ICC= 0.87), fragmentation index (ICC= 0.87), sleep efficiency (ICC= 0.91, and wake after sleep onset (ICC= 0.93). Sleep latency provides moderate agreement after at least 7 days of wear (ICC= 0.72). Given that four measures of sleep provide good reliability after 7 days, and one measure provides at least an acceptable level of agreement, we suggest the MW8 requires at least 7 days of consecutive wear to provide reliable estimates of sleep. Although our Spearman-Brown analyses indicate reliable estimates of fragmentation index, sleep efficiency, and wake after sleep onset can be achieved from <7 days of monitoring for both older adults with and without MCI, we also determined that ≥7 days of wear-time is needed to achieve a reliable estimate of sleep duration in older adults with MCI. Hence, we suggest that future investigations into the sleep of older adults with and without MCI should measure wrist-worn actigraphy for a period of at least 7 days.

Few studies have examined the number of nights needed to reliably estimate sleep. Acebo and colleagues (39) determined the reliability of the Mini Motionlogger wrist-worn actigraph (Advanced Model, Ambulatory Monitoring Inc.) for measuring sleep in 169 young children (aged 1-5 years) and 55 adolescents (11-16 years). The results of this study indicated that 5 nights of monitoring was enough to provide good estimates of sleep in both young children and adolescents. A recent analysis of the MW8 in middle-aged men and women suggested that ≥7 days of observation was enough to provide reliable estimates of sleep (40), however we are only aware of two studies which have examined the reliability of sleep measures for older adults (25, 41). Wohlgemuth and colleagues (41) determined that 7 nights of monitoring using sleep logs and polysomnography was enough to reliably estimate sleep duration, sleep efficiency, and time in bed in both healthy older adults (N= 32) and older adults with primary insomnia (N= 32). More recently, Van Someren (25) determined that 7 nights of sleep monitoring using the Actiwatch (Cambridge Neurotechnology, Cambridge, UK), provides good estimates of reliability for sleep duration and sleep efficiency in both older adults with primary insomnia (N= 10) and older adults with dementia (N= 12). Our study of older adults with and without MCI appears to echo these results and further indicates that estimates of sleep can be reliably measured using 7 nights of actigraphy monitoring.

Our results also indicate that older adults with MCI have poorer sleep than their healthy cognitive peers. We determined that older adults with MCI have lower subjective and objective sleep duration than those without MCI after adjusting for age, sex, and sleep medication use. We also found that older adults with MCI appear to have more consistent fragmentation indices from night-to-night, but less consistent sleep duration from night-to-night. While these differences in ICCs do not warrant different monitoring protocols —given that 7 days of wear time provides good estimates of reliability for sleep duration and fragmentation index irrespective of cognitive status—it is interesting that older adults with MCI have different sleep patterns. One plausible explanation is that MCI associated changes in sleep quality include less regularity in sleep duration (with a tendency towards shorter sleep durations than cognitively healthy older adults) and consistently greater sleep fragmentation. This lower consistency in sleep duration from night-to-night appears to suggest that older adults with MCI might have less homeostatic sleep drive (i.e., Process S) than their healthy cognitive counterparts. It is also plausible that underlying changes in the brains of older adults with MCI – such as neural atrophy, nocturnal hypoxia, and altered neuromodulation – might alter their sleep (20). For example, older adults with MCI have greater amounts of Aβ accumulation (42), and greater Aβ load is associated with more disrupted sleep (43). Future research should therefore examine why older adults with MCI experience different sleep patterns than their healthy cognitive counterparts, since these underlying differences could be related to their increased risk of dementia (5).

While 7 days of wear-time provides good agreement for sleep duration, fragmentation index, and wake after sleep onset, this monitoring protocol only provides moderate agreement for sleep latency. However, sleep latency is difficult to accurately and reliably determine—even using polysomnography (44, 45). Actigraphic assessments of sleep latency are even more challenging since individuals with poor sleep tend to lie in bed motionless, but awake, for long periods of time (46). Sleep latency may thus be difficult

to accurately and reliably estimate using currently available field methods, and associations between sleep latency and cognitive health should be treated with caution.

Limitations and Future Research

Our study has only determined the reliability of MW8 in a sample of community-dwelling older adults. Use of this device in diseased populations may not yield accurate estimations of sleep quality after 7 days of measurement. While there is at least preliminary evidence of validity for the MW8 (33-35), there is not yet criterion evidence of validity for the MW8 in older adults. Future research is thus needed to determine the validity of the MW8 for estimating sleep in older adults with and without MCI.

MCI is typically diagnosed using the Petersen criteria: 1) subjective cognitive impairment; 2) objective cognitive impairment according to a MoCA score of <26/30; 3) no functional impairment in activities of daily living; and 4) no dementia (13). However, we did not use a clinical diagnosis of MCI in our study, but rather classified individuals as MCI solely based on a MoCA score of <26/30. All participants were likely free of dementia as they all had an MMSE score of >24/30 (27).

We did not include napping in our calculations for each sleep variable, and thus our estimates of different sleep indices are exclusive to the major sleep period. Information outside of the major sleep period can be clinically informative, however sleep scoring algorithims for nighttime sleep estimation are not as well validated for scoring of daytime sleeping and naps (24). Thus, future research is needed to examine the reliability of indices of each total 24-hour period of sleep for both older adults with and without MCI.

There are also significant changes which occur in sleep schedules, sleep architecture, and other aspects of sleep quality from middle-age to old-age (2, 3, 20), and it is possible that the younger-older adults of our sample may have significant differences in sleep-wake patterns compared with the older-older adults. Our results should be applied with caution to older adults with significant sleep disturbances as well as older adults with chronic conditions, as these individuals may require different observation periods than our sample. Although we confirmed event-marker time stamps with the CSD to determine when a participant was awake and out of bed according to current actigraphy guidelines (24), it is possible that the last awakening during each sleep window did not coincide with the time participants got out of bed. Future research is needed to establish more accurate field methods for determining when older adults are awake and out of bed.

Our analyses were limited to five markers of sleep quality that are estimated by the MW8 (i.e., sleep duration, fragmentation index, sleep efficiency, sleep latency, and wake after sleep onset). We cannot provide guidance for other potential markers of sleep quality that may be estimated by the MW8. Other actigraphs will likely require different observation periods in order to collect reliable estimates of sleep quality.

Conclusions

In summary, the results of this study indicate that at least 7 days of MW8 wear-time is appropriate for population-based field studies involving older adults. We determined that the MW8, an actigraphy device commonly used to measure physical activity (22, 26), provides reliable estimates of sleep for older adults with and without MCI after at least 7 days of observation. While there are differences in sleep quality based on cognitive status, similar measurement protocols can be used for older adults with MCI and those without MCI. These results provide researchers with a reliable tool to examine differences in sleep (as well as physical activity) in older adults with and without cognitive impairment, which may have future impact on the prevention of cognitive decline.

Declarations

Ethics approval and consent to participate

Ethical approval for this study was obtained from the Vancouver Coastal Health Research Institute and the University of British Columbia's Clinical Research Ethics Board (H14-01301). All participants provided written informed consent.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Author Contributions

RSF and TLA conceived the study concept and design. RSF wrote the first draft of the manuscript, performed all data analyses, and interpreted the results. PCYC was responsible for data collection and management. CKB, PCYC, and TLA each wrote portions of the manuscript and provided critical review. All authors approved of the final manuscript.

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Abbreviations

Aβ: Amyloid-beta; ANCOVA: Analysis of Covariance; BMI: Body Mass Index; CI: Confidence Interval CSD: Consensus Sleep Diary; ICC: Intraclass Correlation; $ICC_{1,1}$: Single Absolute Intraclass Correlation; $ICC_{2,}k$: Average Random Raters Intraclass Correlation; MCI: Mild Cognitive Impairment; MMSE: Mini-Mental State Exam; MoCA: Montreal Cognitive Assessment; MW8: MotionWatch8© wrist-worn actigraph; PSQI: Pittsburgh Sleep Quality Index.

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Tables

Table 1. Participant Characteristics Mean (SD) or %

Participant Characteristic	All Participants (N= 151)	Older Adults without Mild Cognitive Impairment (N= 69)	Older Adults with Mild Cognitive Impairment (N= 82)	p-value*
Age	71.19 (7.26)	69.42 (6.36)	72.67 (7.66)	<0.01
%Female	66.89 %	76.81%	58.54%	0.03
Body Mass Index (kg/m^2)	26.71 (5.05)	25.91 (5.16)	27.45 (4.87)	0.13
%Retired	77.48%	78.26%	76.83%	0.99
Education				
Less than high school diploma	4.64%	1.45%	7.32%	0.26
High school diploma	13.91%	14.49%	13.41%	
Trade school	11.26%	7.25%	14.63%	
Some university	15.89 %	14.49%	17.07%	
University degree or higher	54.30%	62.32%	47.56%	
Smoking History				
Current Smoker	1.32%	1.45%	1.22%	0.96
Past Smoker	49.67%	50.72%	48.78%	
Non-Smoker	49.01%	47.83%	50.00%	
Comorbidities				
Hypertension	26.49%	17.39%	34.15%	0.03
Hypercholesterolemia	17.22%	13.04%	20.73%	0.30
Arthritis	13.25%	13.04%	13.41%	0.99
Mood Disorder	7.95%	10.14%	6.10%	0.54
Hypothyroidism	15.89%	20.23%	12.20%	0.26
Cardiovascular Disease	16.56%	7.25%	24.39%	<0.01
Diabetes Mellitus	2.65%	1.45%	3.66%	0.74
Cancer	1.99%	0.00%	3.66%	0.31
Number of Medications	2.27 (2.15)	2.01 (1.75)	2.49 (2.43)	0.17
Sleeping Medication Use	13.25%	17.39%	9.76%	0.26
Diagnosed Obstructive Sleep Apnea	3.57%	0.00%	7.17%	0.99
CPAP[1] Use	3.57%	0.00%	7.17%	0.99
MMSE[2] Score	28.89 (1.11)	29.22 (0.87)	28.61 (1.21)	<0.01
MoCA[3] Score	24.79 (2.83)	27.19 (1.10)	22.77 (2.19)	<0.01
Pittsburgh Sleep Quality Index Measures				
Total Score	7.28 (4.00)			

		6.62 (5.44)*	7.47 (4.71)*	0.15*
Subjective Sleep Duration (min/day)	373.60 (73.43)	393.89 (111.30)*	363.23 (96.99)*	0.01*
MotionWatch8 Sleep Measures				
Sleep Duration (min/day)	401.10 (51.23)	415.75 (79.05)*	390.18 (68.87)*	<0.01*
Fragmentation Index	31.17 (11.03)	30.51 (16.68)*	32.71 (14.76)*	0.23*
Sleep Efficiency	82.57 (6.10)	82.95 (9.06)*	82.05 (8.52)*	0.40*
Sleep Latency (min/day)	6.72 (9.00)	6.14 (13.70)*	7.35 (11.88)*	0.41*
Wake After Sleep Onset (min/day)	85.70 (34.43)	84.92 (53.52)*	87.78 (47.40)*	0.63*
Wake After Sleep Onset (min/day)	85.70 (34.43)	84.92 (53.52)*	87.78 (47.40)*	0.63*

*P-values refer to group differences (i.e., t-tests, chi-square, or ANCOVA) between Older Adults with Mild Cognitive Impairment and those without

[1]Continuous Positive Air Pressure Machine

[2]Mini Mental State Exam

[3]Montreal Cognitive Assessment

**Controlling for age, sex, sleep medication use*

Table 2. Reliability Coefficients

		Intraclass Reliability Coefficients (95% CI)				*Days of Monitoring Required to Achieve Acceptable Reliabilities of*		
		1 Day	4 Days	7 Days	14 Days	0.7	0.8	0.9
All Participants (N= 151)	Sleep Duration	0.46 (0.40, 0.52)	0.71 (0.63, 0.78)	0.84 (0.80, 0.88)	0.92 (0.89, 0.93)	2.74	4.70	10.57
	Fragmentation Index	0.55 (0.49, 0.61)	0.82 (0.76, 0.86)	0.90 (0.87, 0.92)	0.94 (0.93, 0.95)	1.91	3.27	7.36
	Sleep Efficiency	0.63 (0.57, 0.68)	0.83 (0.78, 0.87)	0.92 (0.90, 0.94)	0.96 (0.95, 0.97)	1.37	2.35	5.29
	Sleep Latency	0.33 (0.27, 0.39)	0.40 (0.23, 0.55)	0.73 (0.66, 0.79)	0.86 (0.83, 0.89)	4.74	8.12	18.27
	Wake After Sleep Onset	0.64 (0.59, 0.70)	0.85 (0.81, 0.89)	0.93 (0.91, 0.94)	0.96 (0.95, 0.97)	1.31	2.25	5.06
Older Adults without Mild Cognitive Impairment (N= 69)	Sleep Duration	0.52 (0.43, 0.62)	0.75 (0.64, 0.84)	0.86 (0.81, 0.91)	0.93 (0.91, 0.95)	2.15	3.69	8.31
	Fragmentation Index	0.44 (0.35, 0.54)	0.75 (0.63, 0.83)	0.85 (0.79, 0.90)	0.91 (0.88, 0.94)	2.97	5.09	11.45
	Sleep Efficiency	0.61 (0.53, 0.70)	0.82 (0.74, 0.88)	0.91 (0.87, 0.94)	0.95 (0.94, 0.97)	1.49	2.56	5.75
	Sleep Latency	0.31 (0.23, 0.41)	0.37 (0.08, 0.58)	0.73 (0.62, 0.82)	0.85 (0.80, 0.90)	5.19	8.90	20.03
	Wake After Sleep Onset	0.58 (0.50, 0.67)	0.83 (0.76, 0.89)	0.91 (0.88, 0.94)	0.95 (0.93, 0.95)	1.69	2.90	6.52
Older Adults with Mild Cognitive Impairment (N= 82)	Sleep Duration	0.40* (0.32, 0.49)	0.65* (0.51, 0.76)	0.80 (0.73, 0.86)	0.90 (0.86, 0.93)	3.50	6.00	13.50
	Fragmentation Index	0.61** (0.53, 0.69)	0.84* (0.78, 0.89)	0.91* (0.88, 0.94)	0.95** (0.94, 0.97)	1.49	2.56	5.75
	Sleep Efficiency	0.64 (0.57, 0.72)	0.84 (0.77, 0.89)	0.92 (0.89, 0.95)	0.94 (0.92, 0.96)	1.31	2.25	5.06
	Sleep Latency	0.35 (0.27, 0.44)	0.48 (0.28, 0.65)	0.73 (0.63, 0.81)	0.87 (0.83, 0.91)	4.33	7.43	16.71
	Wake After Sleep Onset	0.68*	0.86	0.93	0.97*	1.10	1.88	4.24

	(0.61, 0.75)	(0.81, 0.91)	(0.91, 0.95)	(0.95, 0.98)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryMaterialS1RCode.docx
- SupplementaryMaterialS2SensitivityAnalysis.docx