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# Physical activity and self-reported sleep quality in adults with multiple sclerosis

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## Abstract

**Background:** There is a fourfold higher prevalence of sleep problems in multiple sclerosis (MS) than the general population.

**Objective:** This study examined cross-sectional associations among device-measured sedentary and physical activity behavior with perceived sleep quality in adults with MS.

**Methods:** Adults with MS (N=290) completed the Pittsburgh Sleep Quality Index (PSQI) and wore an accelerometer for seven days providing a measure of time spent in sedentary behavior, light physical activity (LPA), and moderate-to-vigorous physical activity (MVPA) using MS-specific cut-points. We conducted multiple linear regression analysis to identify the independent contributions of variables for explaining PSQI scores.

**Results:** The overall model accounted for 2% of the variance in global PSQI scores, and MVPA was significantly and independently associated with global PSQI scores ($\beta=-0.123$; $P=0.045$; partial $r=-0.118$) when accounting for average wear time, sedentary behavior, and time spent in LPA. There were no other significant associations with PSQI global score.

**Conclusions:** Our results suggest that time spent in MVPA may be associated with better sleep quality in adults with MS, but adults with MS do not spend sufficient time in physical activity. Researchers should evaluate these relationships in longitudinal study designs and behavior change interventions, as physical activity may provide a unique opportunity to improve sleep quality outcomes.

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**Keywords**

multiple sclerosis; sleep quality; physical activity; sedentary behavior

## Introduction

Multiple sclerosis (MS) is an immune-mediated disease of the central nervous system with secondary neurodegenerative processes[1] that can manifest as declines in mobility and cognitive functions as well as symptoms of fatigue, anxiety, and depression. Another important consequence of MS is sleep dysfunction. Indeed, there is a fourfold increase in the prevalence of sleep problems in MS compared with healthy adults, whereby 60% of adults with MS report sleep abnormalities [2] Sleep dysfunction may further worsen symptoms of fatigue and depression, cognitive dysfunction, fall risk, cardiovascular risk, and functional capacity in adults with MS.[2] This underscores the need for identifying targets for the safe and effective management of sleep problems in MS.

Physical activity represents a promising approach for the management of sleep problems in persons with MS, as there is evidence for the benefit of physical activity and exercise for managing a number of symptoms and consequences of MS [3, 4], including sleep impairments. Physical activity and exercise interventions in adults with MS have demonstrated improvements in subjective and objective sleep quality as well as a number of sleep parameters (e.g., awakening after sleep onset, daytime sleepiness) [5–8]. There further is evidence of a relationship between physical activity and sleep quality measured subjectively [9] and objectively with device-measured physical activity and sleep parameters [10].

Based on an activity continuum perspective [11], another important correlate of sleep quality in persons with MS might include sedentary behavior. Sedentary behavior, representing the opposite end of the spectrum from physical activity, is highly prevalent in MS [12], and people with MS often engage in more sedentary behavior as a means of energy conservation for the management of other symptoms [13, 14]. Outside of MS, one study demonstrated that higher levels of sedentary behavior were associated with worse sleep quality in young adults from the general population [15]. This suggests that the rate of sedentary behavior might account for the worsening of MS-related symptoms and consequences that could further worsen sleep quality. Such a possibility underscores the importance of understanding sedentary behavior and sleep in MS. Yet, we are unaware of research that has examined this relationship in persons with MS, and there is little understanding of the relationships among sedentary behavior, physical activity, and sleep quality among adults with MS.

The present study examined the relationship among device-measured sedentary and physical activity behavior with parameters of perceived sleep quality in adults with MS. Based on the aforementioned evidence for the benefits of physical activity for sleep quality, we anticipated that more time spent in physical activity would be associated with better sleep quality. We further anticipated that more time in sedentary behavior would be significantly associated with worse sleep quality.

## Materials and Method

### Participants

The data were pooled across two observational studies with overlapping content [16, 17] for generating a larger sample for greater power and precision in this secondary analysis. One study recruited locally through advertisements in the community, the National MS Society, local MS chapters, the Lakeshore Foundation, and the University's MS Center, whereby a cover letter and flyer were sent to individuals and interested persons were asked to contact the research team by telephone or email for further information about the study. Participants were included in the study if they met the following criteria: (1) between the ages of 20-79; (2) ambulatory with or without assistance; and (3) relapse free for at least 30 days. There were 151 participants who met inclusion criteria, completed all relevant measures, and were included in the current study.

The other study recruited a sample of persons with MS nationally through the North American Research Committee on Multiple Sclerosis (NARCOMS) patient registry, whereby NARCOMS staff distributed letters among a random sample of 1,000 persons with MS who completed the Fall 2017 biannual survey. Interested persons contacted the research team and were assessed for the following inclusion criteria: (1) 18 years or older; (2) diagnosis of MS; and (3) member of the NARCOMS registry. Of those who returned materials, 139 persons with MS completed all measures and were included in the current study. Overall, the total sample between studies included 290 persons with MS.

### Physical Activity and Sedentary Behavior

Participants wore an ActiGraph GT3X+ accelerometer on a belt around the waist over a 7-day period as a device-measure of physical activity and sedentary behavior. This model of ActiGraph accelerometer has acceptable accuracy in MS across a range of walking speed and levels of neurological disability [18]. Participants were asked to wear the monitor only during waking hours, whereby they put the monitor on when getting out of bed in the morning and removed the monitor when getting into bed for the night. Participants recorded in a daily log the date and time that the accelerometer was worn, and this log was used to verify the dates of wear time during data processing. Accelerometer data were downloaded, daily wear time was estimated using the Troiano 2007 algorithm in the ActiLife software, and the data were processed into 60-second epochs with low frequency extension (LFE). Data were delineated into moderate-to-vigorous physical activity (MVPA) based on a MS-specific cut-point of 1,584 counts/minute [19] and the value of 100 counts/minute as a cut-point for delineating data into either light physical activity (LPA) or sedentary behavior. Percentage of wear time in each behavior, which was calculated by dividing the time spent in the respective behavior by the average wear time and multiplying by 100. A day of wear was considered valid if there was a minimum of 10 hours (i.e., 600 minutes) of total wear time without continuous zeros exceeding 30 minutes, and participants with 1 or more valid days of data were included in the analyses. The sample included 157 (54%) people with seven valid days, 61 (21%) with six valid days, 35 (12%) with five valid days, 13 (5%) with four valid days, 7 (2%) with three valid days, 11 (4%) with two valid days, and 6 (2%) with one valid day.

## Perceived Sleep Quality

The Pittsburgh Sleep Quality Index (PSQI) assessed the parameters associated with perceived sleep quality with reference to the past month [20]. The PSQI includes 19 items that form seven component scores: (1) subjective sleep quality; (2) sleep latency; (3) sleep duration; (4) habitual sleep efficiency; (5) frequency of sleep disturbances; (6) frequency of sleep medication use; and (7) daytime dysfunction. The seven component scores were calculated to be equally weighted on a scale that ranged between 0 (not during the past month) and 3 (three or more times a week) and then summed into a global PSQI score. Global scores ranged between 0 and 21, and higher scores reflected worse perceived sleep quality. The global score of greater than 5 is indicative of a poor sleeper [20]. There is evidence of internal consistency, reliability, and validity in a number of populations [20–22]

## Demographic and Clinical Characteristics

Participants completed a demographic and clinical characteristics questionnaire for information regarding age, sex, race, MS type, and disease duration. Participants further completed the Patient Determined Disease Steps (PDDS) containing a single item for a measure of self-reported disability status [23,24]. PDDS scores range between 0 (normal) and 8 (bedridden), and the scores have demonstrated evidence for validity and strong correlations with the Expanded Disability Status Scale, pyramidal and cerebellar functional scores, and walking ability in persons with MS [25]. Only participants who were ambulatory without assistance (i.e., PDDS < 4) were included in the present study, as the association between physical activity and outcomes may differ across the disability spectrum, and there are unique guidelines and approaches for behavior change as a function of disability status in MS.

## Procedures

The procedures for both studies were approved by the University's Institutional Review Board, and all participants provided written informed consent before participating in the study. Regarding the local study, the PSQI and demographics questionnaires were collected during a single session in a research laboratory. After the session, participants were provided with the accelerometer and instructions for wearing the device over the subsequent 7-day period as well as a pre-stamped, pre-addressed envelope for return service through the United States Postal Service (USPS). Regarding the national study, all procedures were mail-based whereby participants who verbally volunteered were mailed a packet containing the informed consent document, accelerometer and wear-time log, questionnaires, and a pre-stamped and pre-addressed envelope for return service through the USPS. After completing the questionnaires, participants returned a copy of the signed informed consent along with the study materials through the USPS. All participants were remunerated upon completion of the study and returning the accelerometer.

## Statistical Analyses

All data were analyzed in SPSS Statistics, Version 26 (IBM Corporation, Armonk, NY), and all analyses were interpreted with an *a priori p*-value of 0.05. Descriptive statistics were reported as mean and standard deviation (SD), unless otherwise noted (e.g., median and interquartile range [IQR] or number and percentage). We conducted multiple linear regression analysis to identify the independent contributions of variables for explaining PSQI scores. The dependent variable was the global PSQI score, and time spent in sedentary behavior, LPA, and MVPA were the independent variables. Further, average wear time was included as an independent variable to account for the variability in participant wear time.

# Results

## Participant Characteristics

Participant characteristics and demographic information are presented in Table 1, and by study sample in Supplementary Table 1. The sample (N = 290) had an average (SD) age of 52 (12) years and was primarily Caucasian (80%) and female (82%) with relapsing-remitting MS (90%). The sample had a median [IQR] PDDS of 1 [2] and an average (SD) disease duration of 15 (9) years. Regarding sleep parameters, the sample reported an average of 8.3 (1.3) hours in bed per night with average sleep duration of 7.0 (1.4) hours indicating 85% (15%) sleep efficiency. The majority of participants (77%) reported poor sleeper status (i.e., PSQI > 5) with a mean (SD) Global PSQI of 7.5 (3.8). Regarding accelerometry, the sample had an average wear time of 823.0 (87.1) minutes (i.e., 13.7 hours) per day. The sample spent an average of 510.2 (94.0) minutes (i.e., 8.5 hours) per day in sedentary behavior, 259.6 (81.8) minutes (i.e., 4.3 hours) per day in LPA, and 23.3 (22.0) minutes per day in MVPA. The sample spent an average of 62% of the day in sedentary behavior, 35% of the day in LPA, and 3% of the day in MVPA. Participants in the Nationwide Study were significantly older; had significantly longer disease duration; had significantly lower PSQI Global scores; and were significantly less likely to be physically active (Supplementary Table 1).

## Relationship among Physical Activity, Sedentary Behavior, and Perceived Sleep Quality

The summary of multiple linear regression analysis among sedentary behavior and physical activity predicting subjective sleep quality in adults (N = 290) with multiple sclerosis controlling for average wear time is presented in Table 2. The overall model ($F$[3]=2.170; $p$=0.92; $R^2$=0.022) accounted for 2.2% of the variance in global PSQI scores. MVPA was significantly and independently associated with global PSQI scores ($\beta$=−0.123; $P$=0.045; partial $r$=−0.118) when accounting for average wear time, sedentary behavior, and time spent in LPA. The partial scatterplot for the relationship between time spent in MVPA and PSQI scores is presented in Figure 2, and the data indicated that higher levels of MVPA were weakly associated with better sleep quality. There were no other significant associations with PSQI global score.

# Discussion

We undertook one of the first studies examining the relationships among device-measured sedentary behavior, physical activity, and perceived sleep quality in adults with MS. Our sample included a high proportion (77%) of poor sleepers, and multiple linear regression analysis indicated that more time spent in MVPA was independently, but weakly, associated with perceived sleep quality when controlling for average wear time and time spent in sedentary behavior and LPA. Although not strong, the association was statistically significant indicating that MPVA may be an important correlate of perceived sleep quality in adults with MS.

Our results indicated that more time spent in MVPA weakly and independently contributed to global PSQI scores when controlling for wear time as well as time spent in sedentary behavior and LPA. These results are consistent with a previous study in adults with MS that identified a weak association between subjectively measured sleep quality and subjectively measured physical activity levels in adults with MS [9]. Another study demonstrated a significant improvement in sleep quality outcomes following a six-week moderate-intensity aerobic exercise intervention compared with a home exercise program in adults with MS [8]. However, this may not be true of LPA and sleep, as we did not identify an association between time spent in LPA and sleep quality. Collectively, these results suggest that engaging in more strenuous exercise may improve perceived sleep quality in adults with MS who experience sleep impairments. However, this association was weak in nature, and the model accounted for only 2% of the variation in global PSQI scores. Additionally, our sample spent an average of 23 minutes per day in MVPA, and this is less than the recommended time for attaining the benefits of this health behavior, yet comparable with a previous study estimate of physical activity participation in adults with MS [26]. Thus, adults with MS may not be engaging in sufficient levels of physical activity necessary for maximizing the benefits associated with this health behavior [27]. Collectively, these results suggest that adults with MS who reported sleep impairments may benefit from a behavioral intervention targeting an increase in physical activity, specifically MVPA, for managing sleep quality.

Our results indicated no significant association between time spent in sedentary behavior and sleep quality when controlling for wear time and time spent in physical activity. This is consistent with a recent meta-analysis of studies examining the association between sedentary behavior and sleep problems in the general population [28]. That meta-analysis identified a significant association between subjectively measured sedentary behavior and sleep disturbance, but there was no association between sleep and objectively measured sedentary behavior [28]. This suggests that the perception of time spent in sedentary behavior may be better associated with the perception of sleep disturbance compared with objectively measured sedentary time. Our results suggest that any relationship between sedentary behavior and sleep duration may be associated with time spent in physical activity, specifically MVPA. However, more research is necessary to evaluate these relationships including both subjective (i.e., self-report) and objective (i.e., device-measured, Polysomnography) outcomes of sedentary behavior, physical activity, and sleep.

There are important limitations to consider when interpreting our results. The cross-sectional design of this study precludes any inferences regarding causality; longitudinal research is necessary to further examine the relationships among physical activity, sedentary behavior, and perceived sleep quality in adults with MS. We did not include a non-MS control group that would be required to determine if our results extend beyond persons with MS. We did not screen for the presence of sleep disorders, such as obstructive sleep apnea, that are common in MS and may influence the relationship between sleep quality, sedentary behavior, and physical activity. The PSQI is a validated questionnaire often used to measure aspects of sleep quality in adults with MS, but it is self-report in nature and we did not include an objective sleep outcome (e.g., actigraphy), which may not provide an accurate picture of sleep quality for comparison with device-measured sedentary behavior and physical activity. Additionally, the PSQI asks respondents to answer each component in reference to the previous 4 weeks, whereas our measure of physical activity and sedentary behavior were objective in nature and were captured over a period of 7 days and this may limit the ability to compare these behaviors. Thus, we encourage future research to utilize objective outcomes of sleep (e.g., Polysomnography, actigraphy) in addition to self-reported outcomes of sleep. We did not ask participants to report daytime nap behavior that could influence the volume of sedentary behavior and negatively influence sleep quality. Additionally, the sample had a wide range of age distribution and was primarily Caucasian (66%) with a wide range of disease duration and RRMS (85%), suggesting that our sample may not be fully representative of the MS population. Thus, our results may not be applicable to MS-subgroups outside with differing characteristics (e.g., age, race, disease duration, MS type). Further, we did not include participant characteristics as control variables in the regression model as the influence of demographic characteristics were not the primary focus of this particular study. Future research should further evaluate the influence of participant characteristics in the relationships between sleep, physical activity, and sedentary behavior, as clinical factors may significantly influence both sleep and participation in physical activity. Combining two samples with different sets of inclusion criteria may have influenced the results of this study, as there were significant differences between study samples for demographic and clinical characteristics, sleep parameters, and physical activity parameters (Supplementary Table 1).

This study represents the first to examine the relationships among device-measured sedentary behavior, physical activity, and perceived sleep quality in adults with MS. Our results indicated that a large proportion of the sample with MS was classified as poor sleepers and that more time spent in MVPA was independently associated with better sleep quality. However, there were no significant associations among time spent in sedentary behavior or LPA and sleep quality. Collectively, our results suggest that MVPA may represent a promising non-pharmacological approach to manage sleep impairment in adults with MS, but adults with MS do not spend a sufficient amount of time in physical activity. It is important that future research evaluate these relationships utilizing longitudinal study designs and behavior change interventions, as physical activity may provide a unique opportunity to improve sleep quality outcomes.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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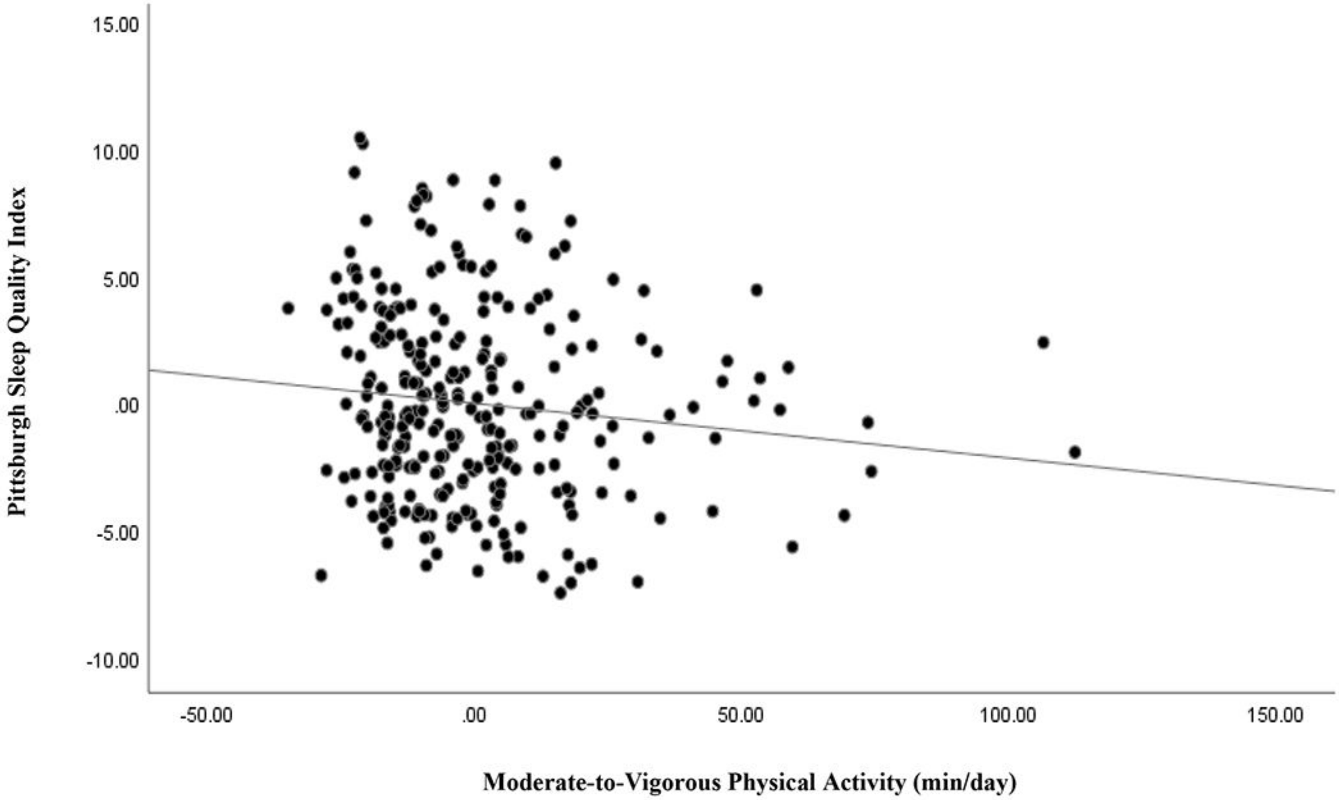


**Figure 1:**

Partial scatterplot along with a line of best fit for the relationship between Pittsburgh Sleep Quality Index global scores and time spent in moderate-to-vigorous physical activity of 290 persons with MS.

**Table 1:**

Participant demographics and clinical characteristics for adults with multiple sclerosis (N = 290).

| | Mean (Standard Deviation) | Range |
|---|---|---|
| **Age (years)** | 52.2 (12.1) | 22-78 |
| **Sex (n (%))** | 238 (82)F / 51 (18)M | |
| **Race (n (%))** | | |
| **Caucasian** | 231 (80) | |
| **Black/African American** | 46 (16) | |
| **Latino/Latina** | 6 (2) | |
| **Other** | 5 (2) | |
| **MS Type (n (%))** | | |
| **Relapsing Remitting MS** | 262 (90) | |
| **Secondary Progressive MS** | 13 (5) | |
| **Primary Progressive MS** | 6 (2) | |
| **Benign** | 5 (2) | |
| **Disease Duration (years)** | 15.0 (9.2) | 0.5-48.0 |
| **PDDS (median [IQR])** | 1 [2] | 0-3 |
| **Sleep Parameters** | | |
| **PSQI Global Score** | 7.5 (3.8) | 0.0-18.0 |
| **Poor Sleepers (n (%))** | 223 (77) | |
| **Total Time in Bed (hours)** | 8.3 (1.3) | 4.0-12.5 |
| **Sleep Duration (hours)** | 7.0 (1.4) | 2.5-12.0 |
| **Sleep Efficiency (%)** | 84.8 (14.8) | 31.8-125.0 |
| **Sleep Onset Latency (min)** | 26.0 (26.4) | 0.0-210.0 |
| **Accelerometry Parameters** | | |
| **Average Accelerometer Wear Time** | 823.0 (87.1) | 627.0-1228.3 |
| **Sedentary Behavior (min/day)** | 510.2 (94.0) | 237.4-830.8 |
| **% Sedentary Time** | 62.1 (9.8) | 25.7-86.6 |
| **LPA (min/day)** | 289.6 (81.8) | 96.0-607.8 |
| **% Time in LPA** | 35.1 (9.0) | 13.3-63.9 |
| **MVPA (min/day)** | 23.3 (22.0) | 0.2-145.0 |
| **% Time MVPA** | 2.8 (2.5) | 0.0-15.6 |

Note: Data are presented as mean (standard deviation) unless otherwise specified. *MS* multiple sclerosis; *PDDS* Patient Determined Disease Status; *IQR* interquartile range; *PSQI* Pittsburgh Sleep Quality Index; *LPA* light physical activity; *MVPA* moderate-to-vigorous physical activity.

**Table 2:**

Summary of multiple linear regression analysis among sedentary behavior and physical activity predicting subjective sleep quality in adults (N = 290) with multiple sclerosis controlling for average wear time.

| | Global PSQI | | | | |
|---|---|---|---|---|---|
| | ***B*** | ***SE B*** | **β** | ***p*-value** | **Partial *r*** |
| **Sedentary Behavior** | −0.005 | 0.003 | −0.115 | 0.103 | −0.096 |
| **LPA** | 0.000 | 0.003 | 0.010 | 0.890 | 0.008 |
| **MVPA** | −0.021 | 0.011 | −0.123 * | 0.045 | −0.118 |

*Notes*: Average wear time was excluded from the model as a non-significant contributor;

* $p < 0.05$.

*PSQI* Pittsburgh Sleep Quality Index; *LPA* light physical activity; *MVPA* moderate-to-vigorous physical activity.