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ORIGINAL RESEARCH

Physical Activity, Sedentary Behavior, and Physical Function in Older Adults With Multiple Sclerosis

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Older adults with multiple sclerosis (MS) experience the combined effects of aging and a chronic, disabling neurological disease on physical activity, sedentary behavior, and physical function. This study examined associations among light and moderate-to-vigorous physical activity (LPA and MVPA), sedentary behavior, and physical function in older adults with MS. Forty older adults with MS (median age = 60 years) who had a median Expanded Disability Status Scale score of 4.5 wore an accelerometer for a 7-day period and completed the Short Physical Performance Battery (SBBP), 6-minute walk (6MW), and timed 25-foot walk (T25FW). LPA was associated with SPPB ($r_s = .551$, $p < 0.01$), 6MW ($r_s = .660$, $p < 0.01$), and T25FW ($r_s = .623$, $p < 0.01$) scores; MVPA was associated with 6MW ($r_s = .529$, $p < 0.01$) and T25FW ($r_s = .403$, $p < 0.01$) scores. There were significant associations between LPA, but not MVPA, with SPPB ($\beta = .583$, $p < 0.01$), 6MW ($\beta = .613$, $p < 0.01$), and T25FW ($\beta = .627$, $p < 0.01$) scores in linear regression analyses. Older adults with MS who engaged in more LPA demonstrated better physical function and therefore LPA might be a target of future behavioral interventions.

Keywords: accelerometry, multiple sclerosis, older adults, physical activity, physical function

There is a significant worldwide shift in the age distribution of persons living with multiple sclerosis (MS). For example, the peak prevalence of MS in Manitoba, Canada occurred at 35-39 years of age, with no documented cases beyond an age of 64 years, in 1984. The peak prevalence was 55-59 years of age, with documented cases of MS beyond 80 years of age, 20 years later in 2004 (Marrie, Yu, Blanchard, Leung, & Elliott, 2010); there is evidence of a similar shift in British Columbia, Canada (Kingwell et al., 2015). This demographic shift is further occurring in other countries (e.g., Italy and the United States of America) (Minden, Frankel, Hadden, Srinath, & Perloff, 2004; Solaro et al., 2015), and is based on the increase in life expectancy of persons with MS (Sanai et al., 2016) and the general aging of the entire population of adults worldwide.

Older adults with MS undergo the effects of normal aging along with a chronic, disabling neurological disease (Stern, Sorkin, Milton, & Sperber, 2010). Older adults with MS report poor health status and functioning, and dependence for activities of daily living (Finlayson & van Denend, 2003; Finlayson, van Denend, & Hudson, 2004; Jones et al., 2013). There is evidence of a faster rate of disability progression among older than younger adults with MS (Trojano et al., 2002), and older age is a primary predictor of reaching disability milestones in MS (Confavreux & Vukusic, 2006). Older adults with MS further have reduced physical function, based on the Short Physical Performance Battery (SPPB), and this coincides with elevated risk for developing future disability (Motl, Chaparro, Hernandez, Balto, & Sandroff, 2016; Motl et al., 2015).

There is increasing interest in the application of physical activity as a behavioral approach for managing declines of physical function among older adults with MS (Motl, Sebastiao, et al., 2016); this parallels the viewpoint of placing more emphasis on behaviors for promoting wellness in MS (Dunn, Bhargava, & Kalb, 2015). This interest further builds upon existing research indicating that reducing sedentary behavior and/or increasing physical activity improves physical function among the general population of older adults (McAuley et al., 2013; McAuley et al., 2012; Wojcicki et al., 2015). Nevertheless, many older adults with MS are not engaging in sufficient amounts of physical activity for accruing the benefits associated with this health behavior (Motl, Sebastiao, et al., 2016). We are aware of one study that reported older adults with MS engaged in less moderate-to-vigorous physical activity (MVPA) and more sedentary behavior than middle-aged and young adults with MS; there were no differences in light physical activity (LPA) as a function of age (Klaren et al., 2016). The rate and pattern of participation in physical activity and sedentary behavior might be associated with a concomitant reduction of physical function among older adults with MS.

We undertook a cross-sectional study that examined the associations between objectively-measured levels of physical activity (i.e., MVPA and LPA) and sedentary behavior with performance measures of physical function in older adults with MS. We examined whether those who engaged in higher levels of MVPA and LPA and lower levels of sedentary behavior would demonstrate better physical function as measured by the SPPB, timed 25-foot walk (T25FW), and 6-minute walk (6MW).

Method

Participants

The convenience sample was recruited over a one-month period in March of 2014 through a research advertisement posted on the website of the National Multiple Sclerosis Society (NMSS). The inclusion criteria for participation were: (a) definite diagnosis of MS that was confirmed in writing by the patient's neurologist; (b) relapse free in the last 30 days; (c) ambulatory with or without assistance (i.e., walk independently or walk with a cane/rollator); (d) age of 55 years or older; and (e) Expanded Disability Status

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Scale (EDSS) (Kurtzke, 1983) score of 6.5 or less (i.e., constant bilateral assistance). We targeted a sample size of 30 or more older adults with MS based on a power analysis using G*Power 3.0 and assumptions of a moderate correlation between measures ($r = .50$), two-tailed alpha = .05, and beta = .20. We assessed 131 persons for eligibility, and 83 were initially excluded for not meeting criteria ($n = 58$), declining participation ($n = 18$), or other reasons ($n = 7$). Of the 48 remaining participants who initially volunteered, only 40 completed data collection including accelerometry and physical performance outcomes.

Measures

Physical activity and sedentary behavior. The participants wore an ActiGraph GT3X+ accelerometer on a belt around the waist during the waking hours of the day for a 7-day period; we did not express the data per day of the week based on previous research (Motl et al., 2007). The model of ActiGraph accelerometer has acceptable accuracy in MS across a range of walking speed and levels of neurological disability, including persons who walk with canes or rollators (Sandroff et al., 2014). Participants recorded wear time in a diary on a daily basis, and further were instructed not to wear the device while sleeping. The data from the accelerometers were processed using ActiLife software for examining wear time and quantifying minutes per day (min/d) of MVPA, LPA, and sedentary behavior; we compared wear time estimates from ActiLife with the diary for consistency in judging a day of data as valid for inclusion in the analysis. We quantified MVPA based on a MS-specific cut-point of 1,584 counts/minute (Sandroff, Motl, & Suh, 2012), and used the value of 100 counts/minute as a cut-point for delineating data into buckets of either LPA or sedentary behavior. All participants had 2 or more days of valid data (i.e., 10 hours of wear time), and the breakdown of cases with 2, 3, 4, 5, 6, and 7 valid days was 2, 3, 3, 6, 7, 19, respectively.

Physical function. The T25FW was administered as a measure of straight-line walking speed over a short distance, as it represents the best-characterized objective measure of ambulation in MS based on its psychometric properties (Fischer, Rudick, Cutter, & Reingold, 1999; Motl et al., 2017; Motl & Learmonth, 2014). As described previously (Fischer et al., 1999), participants completed two trials, and walked as quickly and safely as possible, and the outcome was the mean of the two walks in feet per second.

The 6MW was administered as a measure of walking endurance over a prolonged period of time using standard instructions (Goldman, Marrie, & Cohen, 2008) and has evidence for its valid and reliable use in persons with MS (Goldman et al., 2008; Pilutti et al., 2013; Sandroff, Pilutti, & Motl, 2015). Participants completed the 6MW by walking as fast and far as possible in a single corridor with two, 180 degree turns around cones separated by 75 feet. The outcome was total distance traveled in feet.

The SPPB measures lower extremity function based on standing balance, gait speed, and lower extremity strength (Guralnik, 2016; Guralnik, Ferrucci, Simonsick, Salive, & Wallace, 1995; Guralnik et al., 1994). Standing balance was assessed by asking participants to maintain upright posture while standing with feet in side-by-side, semi-tandem, and tandem positions for up to 10 seconds per test. Those balance assessments occurred in a progressive order wherein participants passed one test in order to attempt the subsequent, more challenging test. Gait speed was assessed based on the time taken by a participant to walk a four-meter course at a normal pace. Lower extremity strength was assessed by a chair stand test in which participants were instructed to sit in and fully rise from a chair five times as quickly as possible, without using arms for support. The three performance assessments were assigned a categorical score ranging from 0 (inability to complete a test) through 4 (highest level of performance) using standardized scoring, and the scores were summed into the overall SPPB score that ranged between 0 and 12 (Guralnik, 2016; Guralnik et al., 1995; Guralnik et al., 1994). Higher scores reflect better lower extremity function, and we have provided recent evidence for its validity in older adults with MS (Motl, Chaparro, et al., 2016).

EDSS. Participants underwent a neurological examination by a Neurostatus Certified examiner for evaluation of functional systems (pyramidal, cerebellar, brainstem, sensory, bowel and bladder, visual, cerebral (or mental), and other) that informed the generation of an EDSS score as a description of neurological disability status (Kurtzke, 1983). The scores range on a scale between 0 (Normal) and 10 (Death due to MS), and scores of 4/4.5 and 6/6.5 represent benchmarks for onset and presence of significant mobility disability.

Procedure

The procedure was approved by a University Institutional Review Board, and all participants provided written informed consent before participating in the study. The data were collected over a one-month period in April of 2014. The physical function data were collected during one session in a research laboratory. Participants further underwent a neurological examination by a Neurostatus Certified examiner for generating EDSS scores as a description of neurological disability status (Kurtzke, 1983). Participants were provided with the accelerometer and associated instructions for wearing it over the 7-day period, and the device was returned using a pre-stamped, pre-addressed envelope that was provided with the accelerometer. Participants received $25 USD for completing the measures and returning the accelerometer.

Statistical Analysis

The data were analyzed in SPSS Statistics, Version 22 (IBM Corporation, Armonk, NY), and many of the variables departed from a normal distribution based on the Shapiro-Wilk test of normality or were ordered-categorical. This necessitated nonparametric descriptive statistics and correlational analyses, when possible. We provide descriptive characteristics of the measures as median and interquartile range (IQR). We conducted Spearman rho rank-order correlations (r_s) between physical activity scores and scores from the measures of physical function, and reported 95% confidence intervals (CIs) for the correlation coefficients. Values for correlation coefficients of .1, .3, and .5 were interpreted as weak, moderate, and strong, respectively (Cohen, 1988), and are reported along with 95% confidence intervals (95% CI). We further conducted multiple linear regression analyses whereby we regressed the individual function outcomes (i.e., those that were associated with physical activity in the bivariate analyses) on physical activity measures with a direct entry of MVPA, LPA, and sedentary behavior; we only included physical activity variables that demonstrated bivariate associations with the functional outcomes. We reported the crude (i.e., unadjusted for other variables besides physical activity and/or sedentary behavior) standardized beta-coefficients as these are interpretable on the same scale as correlation coefficients and squared multiple correlation (R^2) as an effect size estimate for the regression analyses. We did not include additional covariates considering that only 2-3 variables should be included in a model with our small sample size. We further did not include the EDSS as it strongly correlates with physical function outcomes, and its inclusion would therefore leave limited variance in SPPB, T25FW, and 6MW scores for explanation by physical activity and/or sedentary behavior.

Results

Sample Characteristics

The demographic and clinical characteristics of the sample ($N = 40$) are presented in Table 1. The sample had a median age of 60 years (actual range between 55 and 77 years) and was predominately female (75%). Ten of the 40 people were currently employed. The sample largely had relapsing-remitting MS ($n = 28$), and the median disease duration was 18 years (actual range between 3 and 37 years). The median EDSS was 4.5 and indicated that the sample largely had moderate neurological disability. The distribution of EDSS scores was as follows, EDSS 1.5 ($n = 1$), EDSS 2.5 ($n = 3$), EDSS 3.0 ($n = 4$), EDSS 3.5 ($n = 7$), EDSS 4.0 ($n = 3$), EDSS 4.5 ($n = 6$), EDSS 5.5 ($n = 1$), EDSS 6.0 ($n = 13$), and EDSS 6.5 ($n = 2$).

Descriptive Characteristics

The median scores for the measures of physical activity, sedentary behavior, and physical function are in Table 2. Of note, the median scores for MVPA was 4.6 minutes/day, and this is lower than reported for older adults in the general population (i.e., 13.8 minutes/day) (Hart, Swartz, Cashin, & Strath, 2011). Time spent in light physical activity was 221.4 minutes/day, which is lower than reported for older adults from the general population (314.2 minutes/day; Hart et al., 2011). We further note that our sample was engaging in 542.6 minutes/day of sedentary behavior (i.e., 9 hours/day), and this is comparable with 9.4 hours/day in older adults from the general population (Harvey, Chastin, & Skelton, 2015).

Bivariate Associations

The bivariate associations along with 95% CIs for the associations between physical activity/sedentary behavior metrics and physical function outcomes are provided in Table 3. Sedentary behavior was not significantly associated with any of the physical function outcomes. By comparison, LPA and MVPA were positively associated with the physical function outcomes, and the associations were stronger for LPA than MVPA.

Table 1 Demographic and Clinical Characteristics of Older Adults (N = 40) With Multiple Sclerosis

Characteristic	Descriptive Statistic
Age (years)	60 (5.0)
Sex [n (%)]	30 F (75%), 10 M (25%)
MS Type [n (%)]	
Relapsing-Remitting MS	28 (70.0%)
Secondary Progressive MS	3 (7.5%)
Progressive MS	1 (2.5%)
Unknown/Missing	8 (20.0%)
MS Duration (years)	18 (14.0)
Expanded Disability Status Scale (0-10)	4.5 (2.5)

Abbreviations: F = Females, M = Males, MS = multiple sclerosis.
Note. Data are presented as median (IQR) unless otherwise specified.

Table 2 Descriptive Characteristics of Physical Activity Behavior and Measures of Physical Function in Older Adults ($N = 40$) With Multiple Sclerosis

Category	Variable	Median (IQR)
Behavior		
	Sedentary (min/day)	542.6 (86.0)
	LPA (min/day)	221.4 (56.4)
	MVPA (min/day)	4.6 (9.9)
Physical Function		
	SPPB (0-12)	8.0 (3.0)
	6MW (ft)	1,288.5 (563.3)
	T25FW (ft/s)	4.1 (1.9)

Abbreviations: IQR = Interquartile Range; LPA = Light Physical Activity; MVPA = Moderate-to-Vigorous Physical Activity; SPPB = Short Physical Performance Battery; 6MW = 6-minute Walk Test; T25FW = Timed 25-Foot Walk.

Multiple Linear Regression Analysis

The results of the regression analyses are provided in Table 4. The regression analyses all yielded comparable results whereby LPA, but not MVPA, was significantly associated with SPPB, 6MW, and T25FW scores; sedentary behavior was not included in the regression analyses, as it was not correlated with any of the physical function measures in the bivariate analysis. The magnitude of the crude, standardized beta-coefficients (i.e., unadjusted for factors other than MVPA) ranged between |.583| and |.627| for the association between LPA and physical function, and the R^2 values ranged between .306 and .420. Those are strong beta-coefficients, and, along with R^2 values, indicated that the magnitude of association between LPA and physical function might be meaningful in these older adults with MS.

Discussion

This study provided estimates of physical activity and sedentary behavior and associations with physical function in older adults (i.e., age ≥ 55 years) with MS. Our results demonstrated that the older adults with MS accumulated approximately 9.2 minutes per day less MVPA and 92.8 minutes per day less LPA when compared with other data from older adults without MS (Hart et al., 2011). Additionally, older adults with MS spent approximately the same amount of time in sedentary behavior per day compared to older adults without MS (Harvey et al., 2015). This is alarming considering that older adults from the general population are already engaging in low levels of physical activity and high levels of sedentary behaviors (Hart et al., 2011). This high level of sedentary behavior in persons with MS could further compound the negative health effects observed in this population and is important to consider for behavioral interventions. Our results further indicated that LPA was strongly and independently associated with physical function; MVPA had associations in the bivariate, but not multivariate linear regression analyses. These results are important for demonstrating that the growing population of older adults with MS could benefit from behavioral interventions targeting LPA with the objective of improving physical function outcomes. Such a recommendation is consistent with a recent DVD-delivered

Table 3 Summary of Correlations Among Physical Activity Behavior and Measures of Physical Function in Older Adults ($N = 40$) With Multiple Sclerosis

	Behaviorr (95% CI)		
Physical Function Outcome	**Sedentary**	**LPA**	**MVPA**
SPPB	.040 (–.274, .347)	.551 (.290, .736)*	.311 (0, .567)
6MW	.060 (–.256, .364)	.660 (.439, .805)*	.529 (.261, .721)*
T25FW	–.019 (–.328, .294)	.623 (.387, .782)*	.403(.105, .634)*

Abbreviations: LPA = Light Physical Activity; MVPA = Moderate-to-Vigorous Physical Activity; SPPB = Short Physical Performance Battery; 6MW = 6-minute Walk Test; T25FW = Timed 25-Foot Walk.
Note. $*p < 0.01$.

intervention that targeted relatively low-intensity stretching and toning exercise and reported improvements in SPPB scores in older adults with MS (Roberts et al., 2016).

The regression analyses, of note, indicated there were no associations between MVPA and physical function when controlling for LPA; we did not control for sedentary behavior as it did not demonstrate associations with physical function in the bivariate analysis. Such results suggest that higher levels of MVPA don't necessarily correlate with better physical function in older adults with MS. However, our sample reported an exceedingly low level of MVPA with minimal variability compared with another sample of older adults without MS (Hart et al., 2011). Comparatively, a previous study of 312 healthy older adults (age ≥65 years) indicated a strong correlation between MVPA and physical function scores; however, these individuals reported 26.0 minutes per day in MVPA (Santos et al., 2012), and this was substantially larger when compared with the median of 4.6 minutes per day reported in our data for older adults with MS.

There were no significant associations between sedentary behavior and physical function. This was based on bivariate correlation and regression analyses. Such a result suggests that movement, rather than sitting and reclining behaviors, might be better correlates of physical function in older adults with MS. If correct, this would underscore the importance of interventions that target physical activity rather than sedentary behavior for improving physical function, and this should be confirmed through additional intervention trials. We do note that breaks in sedentary behavior might be an importance correlate of physical function in older adults with MS, and this could be examined in future research for clarifying sedentary behavior as a target of interventions.

There are important limitations of this study that should be considered when interpreting our results. We did not include a control, non-MS comparison group. We have a small sample size, and this limits power for detecting smaller correlations and influences the precision of correlation and regression coefficients. The sample further might not be generalizable of older adults with MS considering the median scores for the T25FW and 6MW of 4.1 ft/s and 1,288 ft, respectively. That is, our sample of older adults might have faster walking speed and greater walking endurance than the average older adult with MS. We did not include EDSS scores in the regression analysis, as the scores from this scale are strongly correlated with measures of lower extremity function such as SPPB ($r_s = -.62$), T25FW ($r_s = -.76$), and 6MW ($r_s = -.70$) as well as LPA ($r_s = -.66$) and MVPA ($r_s = -.45$) in this sample. The inclusion of the EDSS in the regression analyses would leave little unique variance for explanation by other variables such as physical activity and/or sedentary behavior. Another limitation is the assumption that the accelerometer cut-off points for sedentary behavior, LPA, and MVPA are applicable among older adults with MS; there currently are no cut-points for processing and interpreting accelerometer data in older adults with MS. These cut-points were developed using a sample of adults with MS between 18-64 years of age who had mild or moderate disability (Sandroff et al., 2012). We note that the accelerometer is accurate for measuring physical activity in the metric of steps across a range of walking speeds, including slow walking, and levels of disability, including those who walk with canes or rollators, in MS (Sandroff et al., 2014); this suggests that it should be accurate in older adults with MS who walk slowly based on disability status, although there is still 12.7% error with slow walking speed (i.e., ~0.45 m/s) that still might be faster than undertaken by people with EDSS scores of 6.0-6.5. We further included ActiGraph accelerometers worn around the waist, and did not capture upper extremity physical activity as a correlate of physical function among the upper extremities. We included persons with 2 or more valid days of data regardless of weekend or week day, based on prior research in MS (Motl et al., 2007), and recognize that there is no universally agreed upon threshold for the number of days necessary for an

Table 4 Summary of Linear Regression Analysis for Variables Predicting Physical Function Outcomes (N = 40)

	SPPB			6 MW			T25FW		
	B	**SE B**	**β**	**B**	**SE B**	**β**	**B**	**SE B**	**β**
LPA	.020	.006	.583*	3.781	.972	.613*	.012	.003	.627*
MVPA	-.008	.045	-.029	4.728	7.239	.099	-.004	.023	-.030
R^2		.306			.420			.370	
F		4.991*			8.210*			6.654*	

Abbreviations: LPA = Light Physical Activity; MVPA = Moderate-to-Vigorous Physical Activity; Sed = Sedentary; SPPB = Short Physical Performance Battery; 6MW = 6-minute Walk Test; T25FW = Timed 25-Foot Walk.
Note. $*p < .01$.

accurate estimate of physical activity. We believe that 2 days is sufficient, and removal of cases with only 2 valid days did not impact the results in an exploratory post hoc analysis. The number of days for a reliable estimate of usual physical activity should become a focus of future research when evaluating associations with outcomes in older adults with MS. The cross-sectional design of this study precludes inferences regarding causality between physical activity and physical function. This is because physical activity could be predictive of physical function, or physical function could be predictive of current levels of physical activity.

We provide objective data on the associations among levels of physical activity and sedentary behavior with physical function in older adults with MS. Older adults with MS who engaged in more light physical activity, in particular, demonstrated better physical function. Such results might be replicated in future research, particularly considering the aforementioned limitations, particularly regarding the accelerometry. We further believe that future research might examine the secondary benefits associated with increasing rates of light physical activity in older adults with MS.

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