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Physical activity and walking performance across the lifespan among adults with multiple sclerosis

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ABSTRACT

Background: There is consistent evidence of an association between physical activity and walking performance in persons with multiple sclerosis (MS). To date, this relationship has been predominantly examined in young and middle-aged adults rather than in the rapidly-growing population of older adults with MS who often times have greater walking problems and are less physically active. This study examined whether physical activity was differentially associated with walking performance across three age groups of young (20–39 years), middle-aged (40–59 years), and older (60–79 years) adults with MS.
Methods: The sample included 124 persons with MS who attended one testing session and provided demographic information, completed the Timed 25-Foot Walk (T25FW) and the Six Minute Walk (6MW) as measures of walking speed and walking endurance, respectively, and wore an accelerometer for a 7-day period.
Results: Trend analysis indicated light physical activity did not significantly differ with increasing age; however, moderate-to-vigorous physical activity (MVPA), walking speed, and walking endurance declined with increasing age. Partial spearman's rank-order correlations between physical activity and walking outcomes that controlled for disease duration, race, and ambulatory disability within each age group indicated that the relationship between MVPA and walking performance was strong among older adults with MS (pr_s for MVPA and T25FW: young = –0.01, middle-aged = –0.16, older = –0.63*; pr_s for MVPA and 6MW: young = 0.10, middle-aged = 0.08, older = 0.68*).
Conclusion: Interventions targeting MVPA may be an appropriate approach for managing walking impairment, particularly in older adults with MS.

1. Introduction

Walking impairment is one of the most prevalent and burdensome consequences of multiple sclerosis (MS) (LaRocca, 2011; Van Asch, 2011). Persons with MS often experience deficits in both walking speed (Phan-Ba et al., 2011) and walking endurance (Goldman et al., 2008), which can adversely impact physical function and quality of life (LaRocca, 2011). This underscores the importance of identifying interventions for managing this pernicious consequence of MS.

One approach for improving walking performance in persons with MS involves the identification of modifiable behaviors that correlate with walking performance that can be targeted through behavior change interventions. An example of such a modifiable behavior is physical activity. There is extensive evidence of a relationship between physical activity and walking performance among persons with MS, such that those who are more physically active demonstrate better walking performance (Motl, 2010; Sandroff et al., 2015; Motl et al., 2013; Kohn et al., 2014; Motl et al., 2011; Snook et al., 2009). Physical activity may influence walking impairment directly or indirectly. Indirectly, physical activity might improve physiological conditioning, leading to reductions in walking impairment (i.e., faster walking speed and greater walking endurance) (Motl, 2010; Sandroff et al., 2015). Additionally, there is experimental evidence such that increasing physical activity reduces walking impairment in persons with MS over time (Baird et al., 2018; Sandroff et al., 2014). There too is evidence of beneficial effects of exercise training, as a subset of physical activity, on walking performance in persons with MS (Snook and Motl, 2009).

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The evidence supporting the potential benefits of physical activity on walking impairment is promising; however, the relationship between physical activity and walking impairment has predominantly been examined in young and middle-aged adults with MS (Motl et al., 2016). There is a dearth of evidence on this association in older adults with MS (i.e., ≥60 years). This is a significant limitation given the rapidly growing prevalence of older adults with MS (Marrie et al., 2010; Ragonese et al., 2008; Buhse, 2015). Of note, older adults with MS represent a subgroup that disproportionately presents with walking impairment (Roy et al., 2017; Bollaert and Motl, 2017). This understudied cohort experiences the effects of MS disease progression coupled with the effects of aging, and the combination of those factors may modify the relationship between physical activity and walking performance.

There is recent evidence highlighting differences in walking performance and physical activity behavior among older adults with MS. Older adults with MS demonstrate worse physical function, including objective walking performance (Roy et al., 2017; Bollaert and Motl, 2017; Motl et al., 2018), participate in less moderate-to-vigorous physical activity (MVPA), and engage in more sedentary behavior than younger adults with MS (Bollaert and Motl, 2017; Klaren et al., 2016). An understanding of whether walking performance and physical activity behavior change with age in persons with MS is important. It further is important to understand the effect of age on the relationship between these two variables as this is critical for the development of efficacious rehabilitation strategies. One might expect that the association would become stronger within a sample that experiences greater, co-occurring changes in both outcomes.

The current study examined the relationship between physical activity and walking performance across the lifespan among adults with MS. We quantified levels of physical activity (i.e., light physical activity (LPA) and MVPA) and walking performance (i.e., walking speed and walking endurance), and further examined the relationship between those variables in young (i.e., 20–39 years), middle-aged (i.e., 40–59 years), and older (i.e., 60–79 years) adults with MS. We hypothesized that (1) levels of physical activity and walking performance would decrease across groups of increasing age; (2) there would be strong associations between physical activity and walking performance overall; and (3) the association between physical activity and walking performance would be strongest among older adults with MS.

2. Methods

2.1. Participants

Participants were recruited through flyers posted in the local community, mailing lists of persons with MS from the University of Alabama at Birmingham (UAB) MS Center database, and advertisements with the National MS Society and regional MS chapters. Those who were interested in participating called the Exercise Neuroscience Research Laboratory and were screened for the following inclusion criteria: (a) age between 20 and 79 years; (b) diagnosis of MS; (c) ambulatory with or without assistance; (d) relapse free for at least 30 days; and (e) willingness to take part in the testing procedures. After being screened for eligibility, participants were categorized into predetermined age groups of young (20–39 years), middle-aged (40–59 years), and older (60–79 years) adults (Klaren et al., 2016).

2.2. Measures

2.2.1. Walking performance

The Timed 25-Foot Walk (T25FW) was administered as a measure of walking speed (Kieseier and Pozzilli, 2012; Motl et al., 2017). Participants were instructed to walk as quickly and safely as possible across a clearly marked 25-foot course from a static start position. Time to complete the course was measured in seconds with greater time indicating slower walking speed. Two trials were administered with the average of the trials in seconds representing the final T25FW time.

The Six Minute Walk (6MW) was administered as a measure of walking endurance (Goldman et al., 2008). Participants were instructed to walk as far and as fast as possible, within the limits of their safety and stability, around a clearly designated circular course free of obstacles for a total of six minutes. The total distance walked was recorded in feet with a shorter distance indicating less walking endurance.

2.2.2. Physical activity

Physical activity was measured with accelerometry (ActiGraph, model GT3X+, ActiGraph LLC, Pensacola, FL). The raw data were downloaded using software (ActiLife 8) and processed into 60-s epochs that were used to determine total wear time and time spent engaging in LPA and MVPA based on established cut points in persons with MS (LPA = 100 to 1583 activity counts/min; MVPA ≥ 1584 activity counts/min) (Sandroff et al., 2012). Activities such as yoga, easy walking, and stretching are examples of light physical activity, whereas fast walking, bicycling, and running are examples of moderate-to-vigorous physical activity (Ainsworth et al., 2011). Days consisting of ≥10 h of wear time were considered valid days and included in the analyses. Wear time and physical activity measures (i.e., LPA and MVPA) were averaged across all valid days and reported as min/day.

2.3. Procedure

All procedures were approved by a University Institutional Review Board and all participants provided written informed consent prior to enrolling in the study. All participants attended a single testing session. The participant initially completed a general demographics questionnaire providing information about age, race, and MS disease type, and then the Patient Determined Disease Steps (PDDS) scale was completed as a measure of ambulatory disability (Learmonth et al., 2013). This was followed by administration of the tests of walking performance. At the end of the session, participants were provided the accelerometer and instructed to wear it during waking hours for 7 consecutive days. Participants further were instructed to record wear time on a log sheet, which was used to cross-reference valid days identified by the accelerometer software. Monitors were worn at the waist over the non-dominant hip and were secured by an elastic belt. Participants mailed the device back to the laboratory through the United States Postal Service in a prepaid, pre-addressed envelope after 7 days of wear.

2.4. Data analysis

Data were analyzed in SPSS Statistics version 25 (IBM Corporation, Armonk, New York). Descriptive statistics are presented in text and tables as mean (SD) unless otherwise noted. Assumptions of normality of the distribution of the physical activity and walking performance outcomes were explored through histograms and assessed with the Shapiro–Wilk's test. Data were further examined for outliers, which were operationally defined as data points ≥ 3 SD from the mean. Data points identified as outliers were winsorized to the next closest value (Dixon, 1960). Differences in demographics and clinical characteristics among the age groups were examined using one-way analysis of variance (ANOVA), Chi-Square statistics, and Kruskal–Wallis tests. To determine if physical activity and walking performance outcomes declined with increasing age, we conducted a trend analysis wherein both linear and quadratic models were examined to determine which pattern of change best fit the data. To determine if physical activity was independently related to walking performance, we conducted partial Spearman rank-order correlations (pr_s) within each age group and when combining all groups (i.e., the overall sample). These partial correlations controlled for disease duration (years), race, and self-reported ambulatory disability status (PDDS) as these variables may influence

Table 1
Demographic and clinical characteristics of participants by age group.

	Age Groups Young (n = 39)	Middle-aged (n = 44)	Older (n = 41)	p-value
Age; years	33.3 (5.0)	48.5 (5.8)	65.8 (4.5)	0.001**
Sex;% female	79.5	72.7	73.2	0.74
Race;% Caucasian	43.6	65.9	82.9	0.01*
Type of MS;% RRMS	87.2	88.6	82.9	0.82
PDDS; Median (IQR)	0.0 (3.0)	1.0 (2.0)	2.0 (3.5)	0.02*
Disease Duration; years	6.7 (5.0)	12.4 (5.8)	19.9 (8.7)	0.001**

Data presented as mean (SD) unless otherwise noted. MS = multiple sclerosis; RRMS = relapsing-remitting MS; PDDS = Patient Determined Disease Steps; * = $p<0.05$; ** = $p<0.01$; Young adults = 20–39 years; Middle-aged = 40–59 years; Older adults = 60–79 years.

walking performance and/or physical activity (Learmonth et al., 2013; Kaufman et al., 2003; Pilutti et al., 2013). The magnitude of correlations was interpreted as small, medium, and large based on values 0.1, 0.3, and 0.5, respectively (Cohen, 1988).

3. Results

3.1. Participant characteristics

Participant demographics are presented by age group in Table 1. There were significant differences in age, race, PDDS, and disease duration among age groups. Sex and type of MS did not significantly differ by age group.

3.2. Physical activity

Accelerometer wear time and time spent engaging in LPA and MVPA are presented by age group in Table 2. Participants with no valid days (young: $n = 5$, middle-aged: $n = 7$, older: $n = 5$) were not included in analyses involving physical activity data. One participant in the middle-aged group and one participant in the older group had MVPA values greater than 4 SD from the group mean, and therefore, those data points were reduced to the next closest value (Dixon, 1960). Average number of valid days ($F = 0.74$, $p = 0.48$) and accelerometer wear time ($F = 1.13$, $p = 0.33$) did not significantly differ by age group. LPA did not differ based on age ($F = 0.24$, $p = 0.62$); each age group engaged in approximately 300 min of LPA (Fig. 1A). Average MVPA across the age groups followed both a linear and quadratic trend; however, the linear model was a statistically better fit for the data indicating MVPA linearly declined across the age groups from youngest to oldest (linear: $F = 6.05$, $p = 0.016$; quadratic: $F = 5.67$, $p = 0.019$; Fig. 1B).

Table 2
Mean values for physical activity and walking performance by age group.

	Age groups Young	Middle-aged	Older	Trend analysis F	p
Valid days; days	4.4 (2.4)	5.0 (2.6)	5.0 (2.4)	–	–
Wear time; min/day	826.6 (104.2)	828.0 (82.0)	796.5 (111.8)	–	–
LPA; min/day	307.0 (100.2)	309.1 (79.8)	296.1 (97.9)	0.24	0.62
MVPA; min/day	21.7 (14.4)	24.6 (17.4)	12.8 (13.1)	6.05	0.02*
T25FW; s	4.7 (1.7)	5.5 (3.5)	6.0 (3.1)	4.45	0.04*
6MW; ft	1584.8 (359.3)	1551.4 (554.5)	1378.3 (404.9)	4.12	0.04*

Data presented as mean (SD). PA = physical activity; LPA = light physical activity; MVPA = moderate-to-vigorous physical activity; T25FW = Timed 25-foot Walk; 6MW = Six Minute Walk; * = significant linear trend.

3.3. Walking performance

Walking performance is presented by age group in Table 2. Trend analysis indicated that time to complete the T25FW increased progressively across the age groups from youngest to oldest ($F = 4.45$, $p = 0.04$; Fig. 1C). There was a significant linear trend indicating 6MW performance decreased across the age groups from youngest to oldest ($F = 4.12$, $p = 0.04$; Fig. 1D).

3.4. Correlations between physical activity and walking performance

Partial correlations between physical activity and walking performance controlling for disease duration, race, and ambulatory disability status are presented in Table 3. LPA was not correlated with walking speed ($pr_s = -0.10$, $p = 0.34$) or walking endurance ($pr_s = 0.08$, $p = 0.45$) in the overall sample. LPA was correlated with walking speed in the older adult group ($pr_s = -0.44$, $p = 0.01$, Fig. 2A). MVPA was moderately correlated with both walking speed ($pr_s = -0.33$, $p = 0.001$) and walking endurance ($pr_s = 0.38$, $p < 0.001$) in the overall sample. MVPA was strongly correlated with both walking performance measures in the older group (T25FW: $pr_s = -0.63$, $p < 0.001$, Fig. 2C; 6MW: $pr_s = 0.68$, $p = 0.68$, Fig. 2D). There were no significant correlations between MVPA and walking performance in the young and middle-aged groups.

4. Discussion

The present study examined the moderating effect of age on the relationship between physical activity and walking performance among adults with MS. The primary result indicated the relationship between engaging in more physical activity and demonstrating better walking performance was strongest among older adults with MS. Within this particular age group, LPA moderately correlated with walking speed, whereas MVPA was strongly correlated with both walking speed and walking endurance. An interesting and unexpected result was the lack of a significant relationship between physical activity and walking performance in younger and middle-aged adults with MS.

The present results for both T25FW and 6MW indicate that walking performance progressively decreased with increasing age. This is not surprising as older adults with MS experience the deleterious effects of aging combined with those of a progressive neurological disease. These results are consistent with evidence from previous research, wherein older adults with MS demonstrated worse physical functioning compared with both younger adults with MS (Roy et al., 2017; Trojano et al., 2002) and age-matched adults without MS (Roy et al., 2017; Bollaert and Motl, 2017; Motl et al., 2018). Indeed, mean walking speed was 1.7 s slower and mean walking endurance was 559.69 ft shorter in our sample of older adults with MS when compared with similarly aged older adults without MS from previous research (mean age = 62.5) (Bollaert and Motl, 2017).

The current results further indicate that MVPA decreased with increasing age, whereas LPA was not modified by age group. This is in line with a previous study that investigated differences in physical activity by age in persons with MS and reported no difference in LPA, but a significant difference between groups for MVPA (Klaren et al., 2016). It is further important to note that, compared to older adults without MS, older adults with MS engaged in a similar amount of LPA; however, the amount of MVPA was a third of what has been previously reported in older adults without MS (Bollaert and Motl, 2017). It is interesting that LPA is seemingly not modified by age, especially in a group of older adults with MS that demonstrated deficits in walking performance. It is possible that the intensity of LPA was lower in older adults with MS (e.g., activity counts between 100 and 800 per minute), whereas younger adults with MS may be moving at a higher intensity (e.g., activity counts between 800 and 1583 per minute), yet, in both instances, these differing intensity levels would be considered LPA.

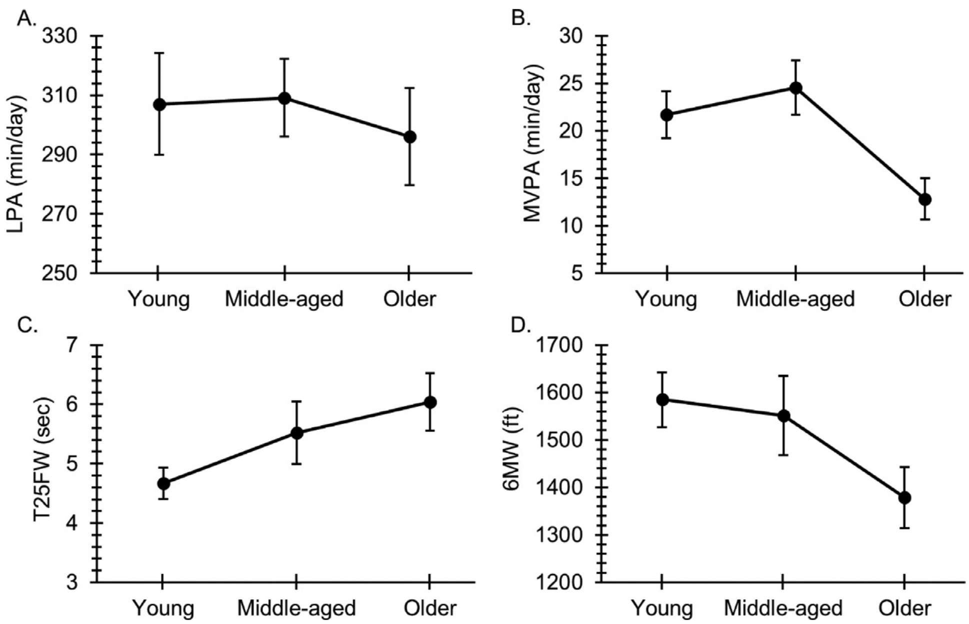

Fig. 1. Physical activity and walking performance by age group. LPA (A) did not significantly decline with age, whereas significant linear trends for MVPA (B), T25FW (C), and 6MW (D) suggest these variables decreased with increasing age. LPA = light physical activity; MVPA = moderate-to-vigorous physical activity; T25FW = Timed 25-foot Walk; 6MW = Six Minute Walk. Error bars represent SEM.

Table 3
Partial Spearman correlations between physical activity and walking performance by age group controlling for disease duration, PDDS, and race.

	LPA				MVPA			
	Young	Middle-aged	Older	Overall	Young	Middle-aged	Older	Overall
T25FW	−0.15	0.15	−0.44*	−0.10	−0.01	−0.16	−0.63**	−0.33**
6MW	0.02	−0.13	0.31	0.08	0.10	0.08	0.68**	0.38**

PA = physical activity; LPA = light physical activity; MVPA = moderate-to-vigorous physical activity; T25FW = Timed 25-foot Walk; 6MW = Six Minute Walk; * = $p < 0.05$; ** = $p < 0.01$.

Nevertheless, the overall decline in walking performance and MVPA with increasing age underscores the need for rehabilitation approaches targeting older adults with MS.

There was a strong and significant correlation between MVPA and walking performance among older adults with MS when controlling for possible confounders of disease duration, race, and disability status. This suggests that MVPA independently influenced walking performance in this age group regardless of other factors that may potentially affect walking performance and/or physical activity (Learmonth et al., 2013; Kaufman et al., 2003; Pilutti et al., 2013). Additionally, walking speed was associated with LPA in the older group. When considering the relationship between LPA and walking performance among older adults with MS, it is important to acknowledge that walking, which was classified as LPA by the accelerometer processing algorithm (Sandroff et al., 2012), is a more metabolically challenging activity for older adults compared to younger adults (Peterson and Martin, 2010). Therefore, walking might be classified more appropriately as moderate physical activity for older adults with MS. This may underscore the importance of MVPA, as opposed to LPA, for eliciting an effect on walking performance in older adults with MS.

Our results suggest that approaches aimed at increasing physical activity may concurrently improve walking performance among older adults with MS, as has successfully been done using behavior change interventions in younger samples of persons with MS (Sandroff et al., 2014; Snook and Motl, 2009). However, we identified only two studies in older adults with MS that examined such interventions (Motl et al., 2016). One study investigated the effects of a DVD-delivered exercise intervention on physical function in older adults with MS and reported modest improvements in function and physical activity (McAuley et al., 2015). Another randomized controlled feasibility trial examined the effect of a home-based, square-stepping exercise program on mobility in older adults with MS and reported small-to-moderate effect sizes for mobility outcomes, including the T25FW (Sebastião et al., 2018). Together with the current results, these studies suggest that interventions aimed at increasing physical activity may concomitantly benefit walking performance in older adults with MS. An important step in continuing this line of research includes identifying theory-based barriers and facilitators of physical activity behavior in this specific segment of the MS population. This will be important for informing the design of behavioral interventions that target such variables for optimally increasing physical activity levels in this cohort of older adults with MS (Motl et al., 2018).

The lack of a statistically significant relationship between physical activity and walking performance in our sample of young and middle-aged adults with MS was unexpected. This result was not consistent with the robust association between walking and physical activity reported in previous studies that included younger adults with MS (Sandroff et al., 2015; Motl et al., 2013, 2011, 2006, 2008; Snook et al., 2009; Motl and Snook, 2008; Weikert et al., 2010). It is important to note that the average age of the samples in those studies ranged between 42.3 years (Motl et al., 2006) and 51.1 years (Motl and Snook, 2008), and therefore, just as with older adults with MS, may not be generalizable among younger adults with MS. This highlights the importance of considering age as an important moderating factor in MS rehabilitation research. Additionally, despite the lack of a significant correlation between walking performance and physical activity in our young and middle-aged groups, it is important to consider that these individuals with MS will continue to age and eventually become older adults with MS. This suggests the importance of promoting physical activity as a lifelong behavior as it will, with time, have a strong influence on one's walking performance.

The current study has several limitations that should be considered when interpreting our results. This study did not include a control, non-MS comparison group, and therefore, it is unclear if our results were

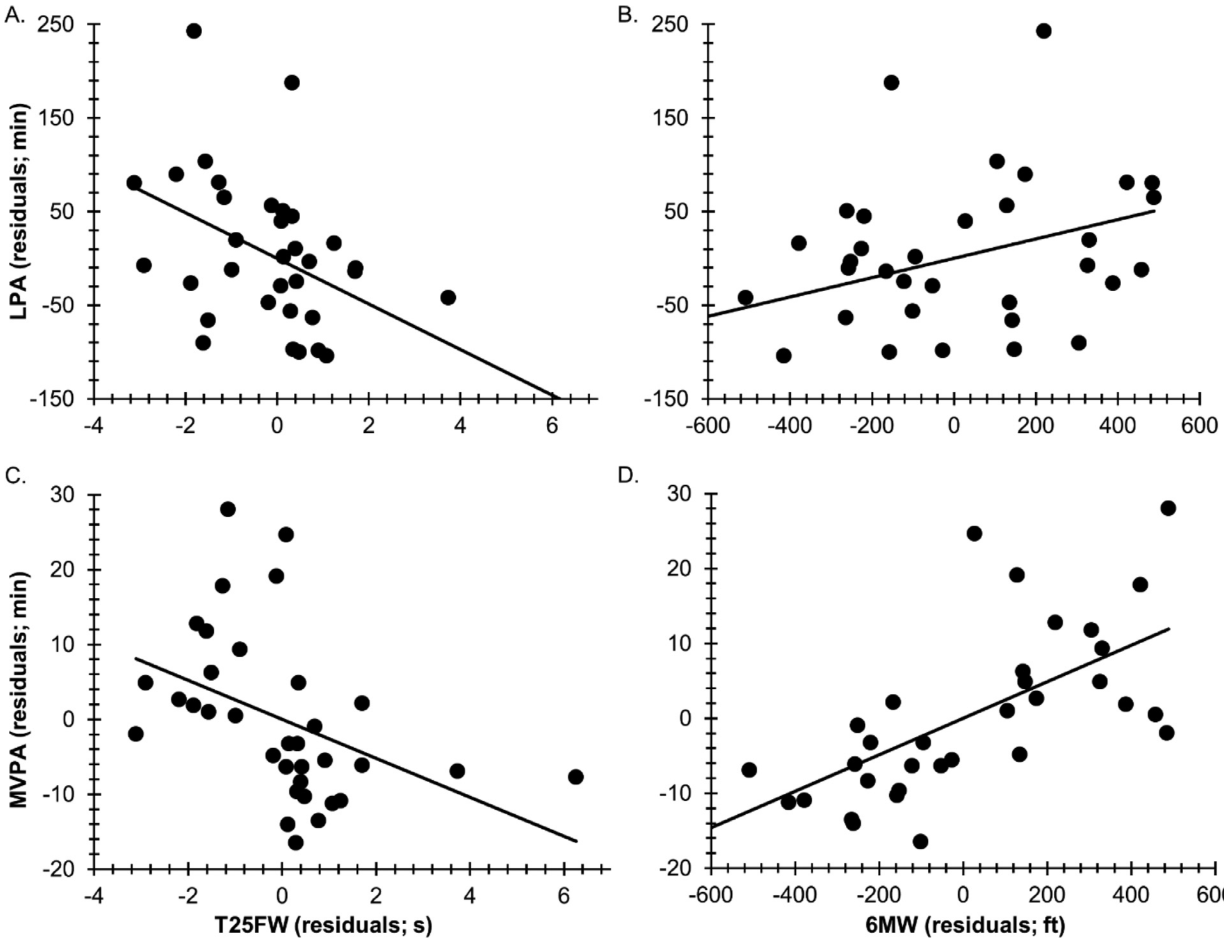

Fig. 2. Scatter plots of residuals from the partial correlations controlling for disease duration, race, and ambulatory disability status in the older group. Correlations between LPA and T25FW (A), MVPA and T25FW (C), and MVPA and 6MW (D) were statistically significant in the older group, whereas the relationship between LPA and 6MW (B) was not. LPA = light physical activity; MVPA = moderate-to-vigorous physical activity; T25FW = Timed 25-foot Walk; 6MW = Six Minute Walk.

selective for aging in persons with MS or aging in general. We relied upon self-report PDDS scores to characterize disability as Expanded Disability Status Scale (EDSS) scores were not measured in this study. Participants were only required to have one valid day of accelerometer data to be included in the analysis, which may not accurately capture typical physical activity behavior levels. The cross-sectional nature of this study precludes us from inferring causality, and further does not allow us to make assumptions of the direction of the relationship between physical activity and walking performance. Whereas previous research that has demonstrated a relationship between physical activity, physiological conditioning, and walking performance (Sandroff et al., 2015) leads us to assume physical activity influences walking performance, it is a possibility that individuals who walk better were able to participate in more physical activity.

5. Conclusion

The present results indicate that MVPA, walking speed, and walking endurance decreased with increasing age, and MVPA was strongly correlated with walking speed and walking endurance among older adults with MS. To that end, interventions that are designed to increase physical activity, specifically moderate-to-vigorous physical activity, may represent an advantageous approach for managing walking impairment particularly among older adults with MS. Physical activity and walking performance were not significantly correlated in younger and middle-age adults with MS, and future research is necessary to identify correlates of walking in these groups. Collectively, the present results highlight the importance of examining associations between variables by age, as age appears to be a moderator of the relationship between physical activity and walking performance in adults with MS.

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Conflict of interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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