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The prospective association of accelerometer-measured physical activity and sedentary behavior and time to Parkinson's disease diagnosis in older women: The Women's Health Study (WHS)

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ABSTRACT

Evidence suggests that individuals diagnosed with Parkinson's Disease (PD) spend less time in moderate-to-vigorous intensity physical activity (MVPA) compared to those without PD. However, prior studies primarily included men and did not consider movement across the entire intensity spectrum. To address these gaps, the association of PD status with total volume physical activity and time spent in sedentary, low light-intensity physical activity (LLPA), high light-intensity physical activity (HLPA), and MVPA among older women was examined. This is a cross-sectional analysis of 17,466 ambulatory women enrolled in the Women's Health Study (WHS) with a median (IQR) age of 70 (67–75) years who were asked to wear an accelerometer for 7 days from 2011 to 2015 for the ancillary study. Reported PD status was assessed via annual mail-in questionnaires prior to device wear. Compared to those without PD (n = 16,661), PD (n = 80) was associated with 98,400 fewer vector magnitude (VM) counts per day and with spending an average of 23.2 more minutes per day sedentary and 10.5 more minutes per day in LLPA. Further, PD was associated with spending 6.4 and 27.3 fewer minutes per day in HLPA and MVPA, respectively, compared to women without PD. PD in women is associated with more daily sedentary time and less time spent in health-enhancing physical activity. Prevention strategies to promote physical activity should be emphasized to enhance health and limit progression of disability in women living with PD.

1. Introduction

Parkinson's Disease (PD) is an age-related progressive neurodegenerative disease resulting in a variety of motor and non-motor symptoms, including bradykinesia, rigidity, loss of postural control, cognitive decline, and sleep disturbance (Kalia and Lang, 2015). The global prevalence of PD doubled from 1990 to 2015 and is now considered the fastest growing neurological disorder in the world (Dorsey et al., 2018; Dorsey et al., 2018). In the U.S., PD affects 667 per 100,000 men [95% confidence interval (CI) 612–732] and 488 per 100,000 women [95% CI 444–543] (Marras et al., 2018). While women have a lower risk of PD (Marras et al., 2018), sex-based differences and gender disparities in care contribute to variations in symptoms, treatment, and disease progression in women, which warrants specific attention (Georgiev et al., 2017; Miller and Cronin-Golomb, 2010). For example, women with PD are less likely to access health care for their PD, are less likely to be referred to a PD specialist, neurologist, or movement disorder specialist, and are underrepresented in clinical trials (Tosserams et al., 2018;

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Pavon et al., 2010; Willis et al., 2011; Thompson et al., 2016). Additionally, women live longer, are less physically active than men, and are more likely to live alone later in life, which may make them particularly vulnerable to worsening disability (The Lancet Public, 2019; Living Longer, 1960; Religion and Living Arrangements Around the World, 2019).

As PD progresses, those affected become less physically active and have greater levels of disability compared to age-matched controls (Lord et al., 2013; Nimwegen et al., 2011; Cavanaugh et al., 2015). A cross-sectional analysis by Nimwegan and colleagues found that self-reported daily physical activity (minutes/day) was 29% lower, compared age matched controls without PD (Nimwegen et al., 2011). Cavanaugh et al followed a small clinical sample of people with PD (n = 17) over two years and found a significant decline in daily steps and time spent in moderate to vigorous intensity physical activity (MVPA) from baseline to year 1 and year 1 to year 2 (Cavanaugh et al., 2015). Similarly, Lord and colleagues found that individuals with PD demonstrated significantly less time per day walking and took fewer steps compared to age-matched controls without PD, with only 3% of incident cases achieving an average of 30 min of walking per day (Lord et al., 2013). These data demonstrate that PD is associated with lower levels of physical activity, with progressive declines in activity over time. Considering several large exercise trials have suggested the disease-modifying effects of regular aerobic physical activity for people with PD, optimizing physical activity levels for this population may be critical for symptom management, slowing the progression of disability, and reducing the risk of other co-morbidities (Schenkman et al., 2018; van der Kolk et al., 2019).

The 2018 Physical Activity Guidelines Advisory Committee Scientific Report provides some evidence of the health enhancing effects of light intensity physical activity (LPA) for other health outcomes, but also highlights the need for further research in this area (Committee, 2018). While there is strong evidence of the added benefit of MVPA for reducing motor disease severity in people with PD, our knowledge of movement across the entire intensity spectrum in this population, including time spent in low light-intensity physical activity (LLPA), high-light intensity physical activity (HLPA) and daily sedentary time is insufficient. As a result, there is a need to characterize physical activity across the intensity spectrum in women with PD.

Device-based physical activity measurement can provide a valid and reliable measurement of total volume physical activity and estimates of time spent in different physical activity intensity categories (Troiano et al., 2008). The overall aims of this paper are to i) characterize physical activity and sedentary behavior of older women with and without PD and ii) examine the association of PD on total volume physical activity and time spent in sedentary, LLPA, HLPA, and MVPA in a large cohort of older women enrolled in the Women's Health Study (WHS).

2. Methods

2.1. Study design and participants

This study is a secondary data analysis of ambulatory women from the WHS who were asked to wear an accelerometer for 7 days between 2011 and 2015 as part of an ancillary study (Lee et al., 2018). Data was received from the National Center for Biotechnology Information (NCBI) database of Genotypes and Phenotypes (dbGaP), a public repository for phenotype data collected through large cohort studies and clinical trials (Mailman et al., 2007). The WHS was designed as a randomized controlled trial (RCT) starting in 1993 to evaluate the effect of low-dose aspirin (Cook et al., 2005; Ridker et al., 2005) and vitamin E (Lee et al., 2005) on the primary prevention of cardiovascular disease and cancer in 39,876 female health care professionals in the United States ≥ 45 years old. Following completion of the trial in 2004, 33,682 living participants (89%) agreed to be part of the WHS observational study, with annual follow-ups via questionnaires that continue to present. From 2011 to 2015, 17,708 (60%) women from the WHS observational study who were asked wear an accelerometer for 7 days to collect data related to physical activity and sedentary behavior wore and returned their device (Lee et al., 2018). Institutional Review Board (IRB) approval was obtained for this study (IRB number: HSC-SPH-21-0453).

2.2. Data collection

Exposure ascertainment: Annual questionnaires in 1993, 2004–2009, 2011, 2013–2015, and 2017–2020 asked participants, "since you last returned a questionnaire (approximately 1 year ago), have you been newly diagnosed with Parkinson's Disease? If yes, please provide the month and year of diagnosis." There was no endpoint adjudication to confirm PD diagnosis.

For this cross-sectional analysis, PD was operationalized as a dichotomous variable; prevalent cases of PD (PD+) are defined as women who reported a diagnosis of PD on any of the annual questionnaires received prior to their wearing the accelerometer. Women who never reported a PD diagnosis on any of the annual questionnaires, before or at the time of the accelerometer recording, were considered free of PD (PD-).

Outcome ascertainment: Physical activity was measured using a protocol described by Lee et al. (2018). In brief, ActiGraph GT3X+ (ActiGraph Corp.; Pensacola, FL) triaxial accelerometers were initialized to sample raw acceleration data at 30 Hz (Hz) and mailed to participants. with a daily log to document accelerometer wear time. Upon receipt, women were asked to wear the accelerometer on a belt around their hip for 7 days during all waking hours, except when bathing or swimming and return the device by mail.

Raw acceleration data were reintegrated and expressed as 15 s epochs. The daily log entries and the Choi wear time algorithm were used to screen for periods of valid wear time and non-wear time (Choi et al., 2011). Total volume physical activity was estimated by calculating the average vector magnitude (VM) counts per day (counts/day) across the number of valid wear days. Time (minutes) spent sedentary, and in LLPA, HLPA, and MVPA in minutes per day was calculated by applying VM data to thresholds established and validated in a cohort of women of similar age (Evenson et al., 2015). Sedentary behavior (SED) was defined as any waking behavior that requires an energy expenditure ≤ 1.5 METs or a rating of perceived exertion (RPE) on the Borg scale (Pradhan and Kelly, 2019) of 6–8, such as sitting, reclining, or laying down. LLPA was any activity with an average MET value of 1.6–2.2 or an RPE of 9–10 and includes household activities such as washing and drying dishes, while HLPA was any activity with a MET value of 2.3–2.9 or an RPE of 11, such as leisurely walking. Finally, MVPA was defined as an activity with a MET value ≥ 3 or an RPE of ≥ 12, such as brisk walking or running (Evenson et al., 2015). The average daily time spent sedentary, and in LLPA, HLPA, and MVPA was estimated by summing the total minutes per day for each intensity specific estimate across all compliant days and dividing by the number of compliant days. Compliant wear time was defined as participants who wore the accelerometer for at least 10 h a day on at least 4 days.

Of the 17,708 women who wore and returned their device, data were successfully downloaded for 17,466 women (99%). A total of 16,741 women (96%) who wore and returned their device met the criteria for compliant wear time and were included in the secondary analysis (Tudor-Locke et al., 2012).

Covariates: The WHS used mail-in questionnaires to collect information on age (years), race and ethnicity (White Non-Hispanic, Hispanic, African American/Black, Asian/Pacific Islander, American Indian/Alaskan native, Other/unknown), cigarette use (never, former current), body mass index (BMI, kg/m^2), and general health status (excellent, very good, good, fair/poor) at the time of the accelerometer recording. Education level (LPN/LVN training, 2-year Associates degree, Diploma program, Bachelor's degree, Master's degree, Doctoral degree), annual income (<$10,000, $10,000-$19,999, $20,000-$29,999,

$30,000-$39,999, $40,000-$49,999, $50,000-$99,999, >$100,000), alcohol consumption (rarely, monthly, weekly, daily) and number of co-morbidities (0, 1–2, >2) was obtained from the annual mail-in questionnaire returned closest to the time of the accelerometer recording from 2011 to 2015.

2.3. Data analysis

Characteristics of participants in the ancillary study (2011–2015) were described using summary statistics. Normally distributed continuous variables were described using mean and standard deviations (SD) and non-normal continuous variables were described using median and interquartile range (IQR). Categorical variables were described using frequencies and percentages. Since the proportion of missing data was<5% for all variables, complete case analysis (listwise deletion) was used.

Multiple linear regression was used to model the associations of PD and total volume physical activity (counts/day) and time spent sedentary, and in LLPA, HLPA, and MPVA (minutes/day). An age-adjusted model (Model 1) and a fully adjusted model (Model 2) including age, wear time, and potential confounders were fit for total volume PA and time spent sedentary, and in LLPA, HLPA, and MVPA. Bivariable regressions with a p-value < 0.20 was used to identify potential confounders to include in the preliminary model. Significant covariates included age, BMI, race and ethnicity, education, income, general health status, number of comorbidities, cigarette use, and alcohol consumption.

Five preliminary linear regression models were fit, and diagnostics were performed to evaluate the residuals and ensure all assumptions were met. When fitting the preliminary models for total volume PA, HLPA, and MVPA, the assumptions of normality and homoscedasticity were violated, thus transformation of the dependent variables was explored. Three preliminary models were fit following log transformation of the dependent variables and the assumptions of normality and homoscedasticity were then satisfied. A sensitivity analysis was performed to compare the linear model to the log transformed models for total volume PA, HLPA, and MVPA and showed consistency in the direction of the association and model inference for all three models. Therefore, we report results for the untransformed models for ease of interpretation.

Model building used a step wise approach, with an entry alpha = 0.15 and an exit alpha = 0.20, and goodness of fit were evaluated to build parsimonious models. Age is a known confounder and was locked in all five models. Using these criteria, five age-adjusted and five fully adjusted preliminary final models were identified. Regression diagnostics were evaluated and once all assumptions (linearity, normality, constant variance, independence) were satisfied, five final models evaluating the association of PD and 1) total volume physical activity and time spent 2) sedentary, and in 3) LLPA 4) HLPA and 5) MVPA were identified. The final models were assessed using the F test and adjusted R^2. All analyses were conducted using Stata version 16.1 (Stata Corp).

3. Results

3.1. Participant characteristics

A total of 80 participants had a reported diagnosis of PD at baseline. Participants had a median (IQR) age of 70 (67–75) years at accelerometer wear, were mostly White women (96%) and had a median (IQR) BMI of 25.4 kg/m^2 (22.7–29.0 kg/m^2). Half (50.3%) of the participants had at least a bachelor's degree and 61.8% of the women reported an annual household income of at least $50,000 per year. 50.5% of participants reported never smoking cigarettes, while 46% were former cigarette smokers and 3.5% were current cigarette smokers. Most women perceived themselves to be in excellent (24.6%) or very good health (50 %) and reported having 1–2 co-morbidities (73.7%) as shown in Table 1.

3.2. Physical activity and sedentary behavior

Participants wore the accelerometer a median of 7 days for 14.9 h per day. The mean (SD) time spent sedentary, and in LLPA, HLPA, and MVPA was 511.4 (98.9) minutes/day, 179.9 (44.5) minutes/day, 108.4 (32.2) minutes/day, and 91.8 (45.4) minutes/day, respectively. Women with PD had a lower total volume of physical activity (376,994 average VM counts/day) and averaged a greater amount of time was per day in sedentary behavior (542.5 min/day) and less time in MVPA (55.6 min/day) compared to women without PD (498,986 average VM counts/day, 511.2 min/day of SED, and 86.6 min/day in MVPA) as shown in Table 2.

As shown in Table 3, after adjusting for age and accelerometer wear time (Model 1), PD in women was associated with an average of 111,500 fewer VM counts/day (β :−111.5, SE: 20.2, p=<0.001), compared to

Table 1
Baseline characteristics of women enrolled in the Women's Health Study (WHS) by Parkinson's Disease status, 2011–2015, N = 16,741.

	PD- (n = 16,661)	PD+ (n = 80)
Covariates		
Age (years), median (IQR)	70 (67–75)	72 (67.5–77)
BMI (kg/m^2), median (IQR)	25.4 (22.7–29.0)	25.2 (22.7–28.4)
Number of comorbidities, median (IQR)	2 (1–2)	2 (1–2)
Number of comorbidities (n, %)		
0	1,725 (10.3)	11(13.8)
1–2	12,290 (73.8)	52 (65.0)
>2	2,646 (15.9)	17 (21.2)
Education (n, %)		
LPN/LVN training	1,525 (9.3)	9 (11.4)
2-year Associates degree	1,736 (10.6)	11 (13.9)
Diploma program	4,893 (29.9)	18 (22.8)
Bachelor's degree	4,323 (26.4)	18 (22.8)
Master's degree	2,979 (18.2)	17 (21.5)
Doctoral degree	938 (5.7)	6 (7.6)
Income (n, %)		
< $10,000/year	58 (0.4)	0 (0)
$10,000-$19,999	353 (2.2)	5 (6.3)
$20,000-$29,999	1,095 (7.0)	8 (10.0)
$30,000-$39,999	1,867 (11.9)	9 (11.3)
$40,000-$49,999	2,631 (16.7)	13 (16.3)
$50,000-$99,999	7,290 (46.3)	33 (41.3)
> $100,000	2,466 (15.7)	12 (15.0)
Race/Ethnicity (n, %)		
White, non-Hispanic	15,877 (96.1)	75 (93.8)
Hispanic	149 (0.9)	2 (2.5)
African American/Black	254 (1.5)	0 (0)
Asian/Pacific Islander	194 (1.2)	3 (3.8)
American Indian/Alaskan native	34 (0.21)	0 (0)
Other/unknown	20 (0.12)	0 (0)
General Health Status (n, %)		
Excellent	4,113 (24.7)	7 (8.8)
Very good	8,341 (50.1)	32 (40.0)
Good	3,782 (22.7)	27 (33.7)
Fair/Poor	420 (2.5)	14 (17.5)
Cigarette use (n, %)		
Never	8,399 (50.4)	48 (60.0)
Former	7,673 (46.1)	31 (38.8)
Current	588 (3.5)	1 (1.2)
Alcohol consumption, (n, %)		
Rarely	6,335 (38.0)	32 (40.0)
Monthly	1,632 (9.8)	13 (16.3)
Weekly	6,043 (36.3)	27 (33.8)
Daily	2,644 (15.9)	8 (10.0)
Accelerometer compliance		
Number of days of compliant wear time (days), median (IQR)	7 (7–7)	7 (7–7)
Wear time on compliant days (min/day), mean (SD)	891.5 (75.2)	893.1 (86.4)

IQR = interquartile range, co-morbidities = diabetes, hypercholesterolemia, cancer, hypertension, and cardiovascular disease.

Table 2
Description of accelerometer-measured physical activity and sedentary behavior by PD status at baseline, 2011–2015, N = 16,741.

	PD- (n = 16,661)	PD+ (n = 80)
Accelerometer-measured physical activity		
Total volume physical activity (counts/day), median (IQR)	498,986 (379,969–632,240)	376,994 (242,269–535,555)
Average time spent in:		
SED (minutes/day), mean (SD)	511.2 (98.9)	542.5 (87.4)
LLPA (minutes/day), mean (SD)	179.9 (44.4)	190.2 (53.0)
HLPA (minutes/day), mean (SD)	108.4 (32.2)	101.3 (35.7)
MVPA (minutes/day), median (IQR)	86.6 (58.9–118.8)	55.6 (26.2–77.4)

women without PD. When further adjusting for potential confounders (Model 2), the association attenuated but remained significant, such that PD in woman was associated with an average of 98,400 fewer VM counts per day (β :−98.4, SE: 18.7, p=<0.001), relative to those without PD. When examining the association of PD and average daily time spent in different intensity specific categories, there were significant differences in the average time spent sedentary, and in LLPA, HLPA, and MVPA when comparing women with and without PD. On average, PD in women was associated with spending 23.2 more minutes per day sedentary (β : 23.2, SE: 9.1, $p = 0.011$) and 10.5 more minutes per day in LLPA (β : 10.5, SE: 4.5, $p = 0.019$) compared to those without PD. Conversely, PD in women was associated with spending 6.4 fewer minutes per day in HLPA (β :−6.4, SE: 3.2, $p = 0.046$) and 27.3 fewer minutes per day in MVPA (β :−27.3, SE: 4.4, p=<0.001) compared to women without PD. The sensitivity analysis reported in Supplemental Table 1 shows the log transformed models for total volume PA, HLPA, and MVPA.

4. Discussion

In this study, we analyzed data from a large national cohort of older women that included 80 women with reported PD and found that PD was cross-sectionally associated with less time spent in health enhancing physical activity and more daily sedentary time. Findings from this study demonstrate that women with PD accumulate significantly less total volume physical activity (VM counts/day) and spend significantly less time in MVPA and more time sedentary, compared to women without PD. Additionally, when examining the association of PD and light intensity physical activity, women with PD spend significantly more time per day in LLPA (minutes/day) and less time in HLPA (minutes/day), which has yet to be reported in the literature and may have implications for future research in this population.

Previous studies that have examined the physical activity behaviors of individuals with PD have been mostly limited to studies that measure physical activity using self-report methods, include samples with mostly men, or are descriptive in nature (Nimwegen et al., 2011; Cavanaugh et al., 2015; Amara et al., 2019). Findings from a population-based, case-control study demonstrate that older adults with PD report spending 29% less time per day engaged in physical activity, compared to controls (Nimwegen et al., 2011). Similarly, our study found women with PD accumulated 20% less total volume physical activity when compared to women without PD. Another study that measured physical activity in people with mild to moderate PD with an ActiGraph accelerometer was descriptive in nature, with no comparison group. In 79 older adults with PD who wore an accelerometer, the mean total volume physical activity (VM counts/day) was 293,617 VM counts/day, compared to a mean of 400,723 VM counts/day in older women in the present study (Benka Wallén et al., 2015). Although, the differences in total volume estimates may be explained by the age of the cohort and accelerometer processing methods (i.e. epoch length), the results are consistent with the present study and characterize older adults with PD as having low levels of physical activity. A more recent study that objectively measured physical activity in people with early PD also found that older adults with PD spent significantly more time sedentary and less time in MVPA, compared to healthy older adults. In contrast to the present study, they found that people with PD spent significantly less time in LPA, compared to healthy older adults, however this was a small sample of men and women with PD and they did not examine LLPA and HLPA independently. Additionally, they measured physical activity with a Fitbit Charge HR (FBHR) by Fitbit Inc.; a commercially available wearable device that uses a proprietary algorithm to determine intensity specific estimates, which has not been validated in this population (Pradhan and Kelly, 2019).

Device-measured estimates of time spent in different physical activity intensity categories has been largely unexplored in this population and this study provides further evidence of risk factors for compromised health in women with PD. The findings in this study demonstrate that women with PD may be particularly vulnerable to worsening disability, as they spend significantly more time sedentary and less time per day in MVPA, which has been shown to be a key ingredient for managing progression of motor symptoms of PD. However, this study also found that women with PD spend significantly more time in LLPA and less time in HLPA compared to women without PD. This suggests a potential shift in the intensity of daily activity, such that women with PD spend less time in the higher end of the intensity spectrum and more time in the lower end of the intensity spectrum. Given what we know about the benefit of time spent in MVPA for this population, future research investigating light intensity physical activity, as either health enhancing or health compromising, should be explored to inform future prevention strategies.

Current prevention strategies suggest individuals with PD should be

Table 3
Adjusted associations of PD and total volume PA and time spent in SED, LLPA, HLPA, and MVPA multiple linear regression, 2011–2015, N = 16,741.

	Total Volume PA (VM counts per day, 1000, VM ct-d)			**SED (minutes/day)**			**LLPA (minutes/day)**			**HLPA (minutes/day)**			**MVPA (minutes/day)**		
	β (SE)	95% CI	p	β(SE)	95% CI	p	β(SE)	95% CI	p	β(SE)	95% CI	p	β(SE)	95% CI	p
Model 1															
PD +	−111.5 (20.2)	(-151.2, −71.9)	<0.001*	27.6 (10)	(8.1, 47.2)	0.006*	10.2 (4.6)	(1.1, 19.3)	0.027*	−7.2 (3.5)	(-14, −0.4)	0.038*	−30.7 (4.7)	(-39.9, −21.5)	<0.001*
Model 2															
PD +	−98.4 (18.7)	(5.3, 41.1)	<0.001*	23.2 (9.1)	(5.3, 41.1)	0.011*	10.5 (4.5)	(1.7, 19.2)	0.019*	−6.5 (3.2)	(-12.9, −0.18)	0.046*	−27.3 (4.4)	(-36, −18.6)	<0.001*

Referent group = women without PD (PD-); SE = standard error, CI = confidence interval, VM = vector magnitude, *Statistically significant (p < 0.05).
Model 1: adjusted for age and wear time.
Model 2: Model 1 further adjusted for bmi, smoking, race, education, income, general health status, number of comorbidities.

referred to a physical therapist at the time of diagnosis, with follow-up every 6 months, to promote an active lifestyle and maximize physical function (Ellis et al., 2021). Future population-based research that measures disease severity, collects device-based measures of physical activity at multiple time points over the course of the disease, and examines physical activity across the entire intensity spectrum is needed to more thoroughly investigate the bi-directional associations of physical activity and sedentary behavior and PD progression.

5. Strengths and Limitations

This study adds to the existing body of literature by providing population-based estimates from a large cohort of older women using an objective measurement of physical activity and sedentary behavior. Device-measured physical activity provides refined estimates of association and adds to our understanding of the effect of PD on women. PD is more prevalent in men, and as a result, women have been traditionally underrepresented in research. This study addresses that gap and includes a relatively large number of cases of women with PD, compared to previous research.

Limitations that should be considered include the cross-sectional design. This design allowed us to generate estimates of association but is unable to determine causality. Additionally, PD is reported in the WHS via annual questionnaires and was not adjudicated, which increases the risk of misclassification of exposure bias. However, previous work by Ascherio and colleagues in a large cohort of female nurses demonstrated that 95% of self-reported cases of PD in women were confirmed by either by a treating physician or a review of medical records (Ascherio et al., 2001). Additionally, the data did not provide information on disease severity, which is a critical factor to consider when characterizing physical activity and sedentary behavior in this population. Device-based measurement of physical activity captures ambulatory activity but fails to measure activities such as swimming, biking, and weight training. However, walking is the most common type of physical activity among women in the general population and has also been shown to be the most important activity to address in people with PD (Ainsworth, 2000; Nisenzon et al., 2011). Finally, this was a cohort of female health care professionals, who were predominately white and of higher socioeconomic status, which may result in a healthier, more active sample of women. Future work is needed in a more racially diverse population to minimize further health-related inequities in women.

6. Conclusion

To our knowledge, this is one of the first studies to examine the association of PD and physical activity and sedentary behavior in a large cohort of women, using device-based measures of free-living physical activity. Older women with PD are less physically active and more sedentary, compared to older women who are free of PD, which may signal worsening disability and increase their risk for other adverse health outcomes. Additionally, these women spend less time in MVPA, which has been shown to slow the progression of PD motor symptoms and promote health and may mitigate the deleterious effects of high sedentary time. Prevention strategies to promote physical activity should be emphasized to enhance health and limit progression of disability in this population of women living with PD.

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CRediT authorship contribution statement

Jennifer L. Hale: Conceptualization, Methodology, Data curation, Formal analysis, Writing – original draft, Funding acquisition. **Gregory Knell:** Conceptualization, Methodology, Writing – review & editing. **Michael D. Swartz:** Writing – review & editing. **Eric J. Shiroma:** Writing – review & editing. **Terry Ellis:** Writing – review & editing. **I-Min Lee:** Writing – review & editing, Data curation. **Kelley Pettee Gabriel:** Supervision, Conceptualization, Methodology, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2023.102361.

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