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Factors associated with ambulatory activity in de novo Parkinson disease

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Abstract

Background—Objective ambulatory activity during daily living has not been characterized for people with Parkinson disease prior to initiation of dopaminergic medication.

Purpose—To characterize ambulatory activity based on average daily step count and examine determinants of step count in non-exercising people with *de novo* Parkinson disease.

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Methods—We analyzed baseline data from a randomized controlled trial, which excluded people performing regular endurance exercise. Of 128 eligible participants (64.3±8.6 years, mean±SD), 113 had complete accelerometer data, which were used to determine daily step count. Multiple linear regression was used to identify factors associated with average daily step count over 10 days. Candidate explanatory variable categories were: 1) demographics/anthropometrics, 2) Parkinson disease characteristics, 3) motor symptom severity, 4) non-motor and behavioral characteristics, 5) comorbidities, and 6) cardiorespiratory fitness.

Results—Average daily step count was 5362±2890 steps/day. Five factors explained 24% of daily step count variability, with higher step count associated with higher cardiorespiratory fitness (10%), no fear/worry of falling (5%), lower motor severity examination score (4%), more recent time since Parkinson disease diagnosis (3%), and the presence of a cardiovascular condition (2%).

Discussion and Conclusions—Daily step count in non-exercising people recruited for this intervention trial with *de novo* Parkinson disease approached sedentary lifestyle levels. Further study is warranted for elucidating factors explaining ambulatory activity, particularly cardiorespiratory fitness and fear/worry of falling. Clinicians should consider the costs and benefits of exercise and activity behavior interventions immediately after diagnosis of Parkinson disease to attenuate the health consequences of low daily step count. Video Abstract available for more insights from the authors (See Video, Supplemental Digital Content 1)

Keywords

Stepping; walking; locomotion; accelerometry; endurance; human movement system

INTRODUCTION

Habitual low ambulatory activity has been characterized as an early problem for people with Parkinson disease (PD).[1-5] People with PD have low self-reported physical activity[5] and objective levels of ambulatory activity[6] compared to healthy people of similar age, and spend the vast majority of waking time (>90%) in sedentary-to-low intensity activities.[2, 6, 7] Importantly, ambulatory activity declines as the disease progresses, illustrated in both cross-sectional[6] and longitudinal studies.[3, 4] However, ambulatory activity using average daily step count has not been characterized for people prior to onset of dopaminergic medication (i.e., *de novo* PD).

In people with PD who take dopaminergic medications, low ambulatory activity is of clinical concern because lower activity is associated with gait dysfunction[3] and greater self-reported disability.[5] Reduced average daily step count, compared to healthy controls, is observed soon after the onset of PD medical treatment.[6] As such, low ambulatory activity could be one of the earliest indicators of functional decline for people with PD. However, expected daily step counts for people with *de novo* PD are currently unknown.

If ambulatory activity is an indicator of early functional decline, it is reasonable to expect that step counts may be low in de novo PD. It would be important to identify such an early indicator of functional decline, since most motor signs of PD are only recognized after significant (60-80%) death of dopaminergic neurons has occurred.[8, 9] Examining ambulatory

activity early in the disease process may provide evidence to recommend early exercise and physical activity intervention. Thus, measuring and understanding the influence of daily step count in *de novo* PD can provide important information to clinicians and people seeking to mitigate later functional ramifications, while still in the early disease process.

To better understand the problem of low step count in people with *de novo* PD, identification of factors that explain step count variability is essential. A number of factors have been associated with low levels of ambulatory and other types of physical activity in people with and without PD. Variables associated with low activity levels in the general population include older age,[10-12] female sex,[13] low education level,[13, 14] low cardiorespiratory fitness,[15] and high body mass index (BMI).[16-18]

For people with PD on dopaminergic medications, both motor and non-motor symptoms are linked with ambulatory activity.[1, 3, 5] Lord and colleagues (n=98) reported people with PD (H&Y I-III) on dopaminergic medications walked on average 5,423 steps/day compared to a healthy comparison group (n=97) that averaged 7,816 steps/day, over a 7-day period.[6] In addition, fatigue,[19, 20] sleep problems,[21] and fear of falling,[22] have been associated with reduced ambulatory activity in other populations and are also characteristics common to people with PD early in the disease process.[23-25] However, there is little knowledge of factors associated with ambulatory activity in people with de novo PD.

Characterizing average daily step count prior to initiation of dopaminergic medications will add knowledge to the current understanding of ambulatory activity decline with PD progression in the absence of the negative or positive impact of medication. Identifying explanatory variables for step count can provide potential intervention targets to improve ambulatory activity early in the disease process and mitigate negative long-term functional consequences for people with PD. Therefore, the purposes of this study were to: 1) characterize ambulatory activity based on average daily step count and 2) examine possible determinants of step count in people with *de novo* PD who did not perform regular exercise and were recruited to participate in an exercise intervention trial.

METHODS

This study reports baseline data from the Exploratory Study of Different Doses of Endurance Exercise in People with Parkinson Disease (SPARX; NCT01506479), a randomized controlled trial examining the effects of different doses of endurance exercise in people with *de novo* PD.[26] The study protocol, with detailed inclusion and exclusion criteria, has been previously reported.[26] Briefly, diagnosis of PD was made by a neurologist, with inclusion criteria being that participants met the UK Brain Bank criteria for idiopathic PD;[27] Hoehn and Yahr (H&Y) scale[28] stage < III (no postural instability); disease duration < 5 years; and 40-80 years old. Candidates were excluded if using dopaminergic medication (dopamine precursors, dopamine agonists, monoamine oxidase inhibitors), had Beck Depression Inventory[29] scores >16, or were regularly participating (i.e., >2 days per week) in moderate to vigorous endurance exercise (i.e., at least 20 minutes of exercise that produced sweating) in the 4 months prior to enrollment screening. Participants provided written informed consent to participate in the study, which obtained institutional review

board approval at each study site (Colorado Multiple Institutional Review Board, University of Colorado Health Institutional Review Board, Memorial Hospital Institutional Review Board, University of Pittsburgh Institutional Review Board, University of Illinois Chicago Institutional Review Board, Rush University Medical Center Institutional Review Board, and Northwestern University Biomedical Institutional Review Board).

Participants

A total of 128 participants with PD were recruited from the Chicago, Denver, and Pittsburgh metropolitan areas with ambulatory activity data obtained from 113 participants (64.3 ± 8.6 years). Fifty-six percent (n=63) of the included sample were men and MDS-UPDRS motor score was 21.1 ± 8.8, indicating a mild level of motor symptoms (Table 1).[30] Baseline activity monitor data were missing from 15 participants due to data collection errors (n=9), non-compliance for wear time (n=4), or withdrawal prior to data collection (n=2).

Ambulatory Activity Monitoring—Ambulatory activity was monitored during waking hours for all participants over a 10-day period after screening, but before randomization, using waist-worn accelerometer (ActiGraph GT3X [+ and BT], Actigraph, Pensacola, FL). Both accelerometer models included the same 3-axis micro-electro-mechanical system (MEMS) accelerometer, with the GT3X-BT having blue-tooth technology capabilities (note: blue-tooth capabilities of the devices were not used in this study). The accelerometers were selected based on the established validity (moderate to high) and reliability for estimating daily step count in free-living conditions,[31-33] and sensitivity to measurement of steps in people with PD.[2, 34]

Acceleration data were sampled by a 12-bit analog to digital converter at 60 Hz, and processed using commercially available software (ActiLife 5/6, Actigraph, Pensacola, FL). A device firmware algorithm screened out the accelerometer baseline noise level to help accurately accumulate the steps-per-epoch, with epochs being the blocks of time (60 seconds in our protocol) in which steps were averaged. An inclinometer feature indicated device positioning, for identification of non-wear periods.

The accelerometer data were reduced, selecting valid days to include in the analysis as those with >10 hours of valid wear time and a maximum of 90 minutes of non-wear.[35] At least three week days and one weekend day of valid wear time were required for participant inclusion in the analysis (4 participants excluded for non-compliance with wear time). Step count (number of steps/day) was based on the 60-second epochs of accelerometer data collected on the vertical axis and average daily step count for each valid day was calculated for the total wear period (i.e., weekdays and weekend days).

Activity count (total number of accelerometer vector count) was also determined in 60-second epochs and averaged for the total wear period, to characterize the total volume of daily physical activity.[12] Activity count represents the sum of the accelerometer vectors in all three planes and reflects the frequency and intensity of movement, unlike the step count, which reflects steps based on vertical axis acceleration.

Candidate Explanatory Variables—Six groups of candidate explanatory variables for average steps per day were defined, using specific measures within each group: 1) demographics/anthropometrics, 2) PD characteristics, 3) motor symptom severity, 4) non-motor and behavioral characteristics, 5) comorbidities, and 6) cardiorespiratory fitness (VO_2peak) (Table 1).

Demographics and Anthropometrics: Age,[10] sex,[13] education level,[14] and BMI[16] were included as candidate demographic/anthropometric variables accounting for variation in ambulatory activity, as these factors are associated with physical activity in the general population.

Disease Characteristics: Time since PD diagnosis was selected as a candidate variable explaining ambulatory activity, as it has been suggested that ambulatory activity declines over time with PD.[3] In addition, motor subtype [tremor dominant (TD) or postural instability gait disorder (PIGD)] was entered as a candidate variable since the PIGD subtype may be more closely linked to ambulatory activity than the TD subtype. TD and PIGD ratio scores were derived from the Movement Disorder Society-Unified Parkinson Disease Rating Scale (MDS-UPDRS) as described previously.[36]

Motor Symptom Severity: H&Y[37] scores were determined for each participant and the MDS-UPDRS[38] was administered by movement disorder neurologists to assess impairment and severity of PD symptoms. The MDS-UPDRS has four subscales: I-Non-motor Aspects of Experiences of Daily Living (13 items), II-Motor Aspects of Experiences of Daily Living (13 items), III-Motor Examination (33 items), and IV-Motor Complications (6 items).[38] A higher score indicates more advanced disease state. The Motor Complication (IV) section relates to the effects of dopaminergic therapy; participants were not undergoing dopaminergic medications, thus this section score was not included in the analysis. Subscales II and III of the MDS-UPDRS were individually used as candidate explanatory variables representing motor symptom severity. The MDS-UPDRS was chosen over the Unified Parkinson Disease Rating Scale (UPDRS) as a potential predictor of ambulatory activity in *de novo* PD, as the MDS-UPDRS places greater emphasis of capturing very mild disease impairments, along with the presence of a broader range of motor and non-motor disabilities.[38]

Non-Motor and Behavioral Characteristics: Subscale I (Non-motor Aspects of Experiences of Daily Living) of the MDS-UPDRS was used as a candidate variable representing overall non-motor symptom severity. Participants also completed the Modified Fatigue Impact Scale (MFIS),[39] Epworth Sleepiness Scale (ESS),[40] and Parkinson Disease Sleep Scale (PDSS-2)[41] to evaluate levels of fatigue and sleep. The MFIS assesses the effect of fatigue on physical, cognitive, and psychosocial function. The ESS focuses on daytime sleepiness. The PDSS-2 focuses on nocturnal sleep impairment. The three questionnaires are validated and recommended for assessing participants with PD.[39, 42]

Fear/worry of falling was assessed using Item 9 of the PDQ-39, which asks the participant to report how often in the past month he/she “felt frightened or worried about falling.” This item is rated on a 5-point scale (1 “never”, 2 “occasionally”, 3 “sometime”, 4 “often”, 5

"always"). Participants were categorized dichotomously as either having none (1) or any (2-5) frequency of feeling frightened or worried about falling.

Comorbidities: The presence of four comorbidity candidate variables was examined: total number of comorbidities, osteoarthritis, cardiovascular (e.g., hypertension, coronary artery disease), and pulmonary conditions (e.g., asthma, sleep apnea). These measures were captured using a general medical history form at the initial study visit, which included all significant medical history items self-reported to the clinician by the participant. Although participants with disorders of sufficient severity to interfere with ability to perform endurance exercise were excluded from the SPARX study, the presence of osteoarthritis, cardiovascular, and pulmonary medical conditions was not specifically excluded.[26]

Cardiorespiratory Fitness: As part of the screening for the SPARX trial, each participant completed a maximal graded exercise test including measurement of VO_2peak by indirect calorimetry under supervision of a clinician.[43, 44] The test was performed at the walking speed that elicited a heart rate that was 70% of age-predicted maximal heart rate for the participant. If the participant was on beta-blocker medication at the time of the test, the selected walking speed was one that elicited a rate of perceived exertion (RPE) of 4 on a 0–10 Rating of Perceived Exertion Scale.[45] VO_2peak was quantified as the greatest rate of oxygen consumption per minute (normalized by body mass and sampled in 30 s intervals) for the exercise test period.

Statistical Analysis—Descriptive statistics were calculated for all candidate explanatory variables for the total sample and by sex. Univariate associations between average daily step count and each candidate explanatory variable were tested using correlations for continuous variables and ANOVA (or two sample t-test) for categorical variables. Multiple linear regression (MLR) was used to explore factors associated with ambulatory activity, measured as average daily step count. The square root transformation was applied to average daily step count for all modeling due to the skewness of the data. MLR was first performed within each grouping of variables using those significant at $p \leq 0.2$: 1) demographics/anthropometrics, 2) disease characteristics, 3) motor symptom severity, 4) non-motor and behavioral characteristics, 5) comorbidities, and 6) cardiorespiratory fitness. Variables maintaining associations with step count of $p \leq 0.2$ within each group were combined in an overall model, where backward elimination was applied (α=0.10). Data are presented as mean ± SD, unless otherwise stated. All analyses controlled for study site location (3 sites) and were conducted using SAS Enterprise Guide version 6.1.

RESULTS

Mean accelerometer wear time was 13.3 ± 1.6 hours/day with an average of 5,362 ± 2,890 steps/day and 345,870 ± 141,796 activity counts/day (Table 2).[46] Eight variables were identified as having a p-value of ≤ 0.2 in subgroup analyses and were included in the full model (Table 3). After backward elimination, only five variables remained significant at $p \leq 0.1$. Significant explanatory variables in the final model explained a total of 24% of the variability in average daily step count. These included: VO_2peak (10%), fear/worry of falling (5%), MDS-UPDRS motor examination score (4%), time since PD diagnosis (3%),

and the presence of a cardiovascular condition (2%). Higher step count was associated with higher VO_2peak, no fear or worry of falling, lower MDS-UPDRS motor examination score, more recent PD diagnosis, and presence of cardiovascular conditions (i.e., greater activity with a cardiovascular condition).

DISCUSSION

The primary objective of our study was to characterize ambulatory activity, based on daily step count, in non-exercising individuals with *de novo* PD. Average daily step count for our sample was 5,362 ± 2,890 steps/day. Our result was similar to the study by Lord and colleagues,[6] which reported people with PD (H&Y I-III; n=98) walked on average 5,423 steps/day. Additionally, Benka Wallen and colleagues[2] reported people with PD (H&Y II-III, n=95) had an average step count of 4,765 steps/day. Although there is no commonly agreed upon value of daily step count to distinguish physically active vs. physically inactive adults, it has been suggested that 5,000 step/day is associated with sedentary lifestyle in the general population of adults[46] and the mean for our sample is at the low end of the "low active" category (5000-7499 steps/day).[47, 48] In addition, accelerometer-based step counts are typically higher than step count measures from pedometers.[49, 50] Thus, the results suggest that our sample of non-exercising people with *de novo* PD had a low level of ambulatory activity relative to healthy active adults.

The daily step count for non-exercising people with *de novo* PD highlight the importance of identifying barriers to ambulatory activity and considering interventions (e.g., exercise and physical activity behavior modification) immediately after diagnosis of PD if the goal is to mitigate future negative health consequences of low ambulatory activity. This is especially important because while higher doses of dopaminergic medication are not associated with greater ambulatory activity,[1] the effects of exercise and medication are complementary.[x] However, further research is warranted to determine how step count in *de novo* PD relates to healthy cohorts (exercising and/or non-exercising) and whether increasing daily step count would improve the symptoms of the disease or if reduced step count is a beneficial compensatory response to the disease. For example, if reduced step count is a compensation to conserve energy, it is not known if any possible energy conservation would outweigh the known negative consequences of a sedentary lifestyle.[51, 52]

The second aim was to identify explanatory factors of daily step count in non-exercising people with *de novo* PD. We found higher step count in our sample to be associated with higher cardiorespiratory fitness, no fear or worry of falling, lower MDS-UPDRS motor examination score, more recent PD diagnosis, and presence of cardiovascular conditions (i.e., greater activity with a cardiovascular condition). Cardiorespiratory fitness and fear/worry of falling explained the greatest amounts of the variability in average daily step count at 10% and 5%, respectively. These explanatory factors are potential therapeutic targets for future intervention trials, which is particularly important in *de novo* PD because clinical motor and non-motor symptoms are relatively mild prior to onset of dopaminergic medications.

Despite being mildly affected by MDS-UPDRS score, time since diagnosis and motor symptom severity accounted for a combined total of 7% of the variability in average daily step count in our final model. Lower motor symptom severity and less time since diagnosis of PD were associated with higher average daily step count. Ambulatory activity has previously been associated with PD motor symptoms, with higher motor severity linked to lower activity in both cross-sectional[6] and longitudinal data.[3] For example, Cavanaugh and colleagues[3] followed people with PD (H&Y 1-4 at initial enrollment; on dopaminergic medication) period and observed that average daily step count decreased by 1,945 steps and MDS-UPDRS motor examination scores worsened by 7.4 points over a two-year period. Our results add to this knowledge by establishing that even mild motor symptoms are linked to lower ambulatory activity.

Of note, the presence of a cardiovascular health condition was associated with a greater average daily step count, which appears to be counterintuitive. Physical activity and exercise are common recommendations from health professionals, with strong evidence for cardiovascular protective effects. For example, people with coronary artery disease have a 16% reduced risk of mortality for every increased hour of physical activity (defined by the study as ≥100 counts/minute).[53] It is well established that walking programs for patients with cardiovascular conditions are effective at increasing ambulatory activity.[54-57] Thus, it is possible that participants who were aware of their cardiovascular disease may have intentionally increased their ambulatory activity due to recommendations from their physicians. Future study is warranted to examine the relationship between cardiovascular comorbidity and average daily step count.

The association between fear/worry of falling and lower ambulatory activity is consistent with literature for other populations. For example, 41% of older adults who receive home care services report intentional activity restriction due to fear of falling.[22] Our cross-sectional analysis cannot determine if low daily step count was a result of fear/worry of falling. However, the relationship between ambulatory activity and fear/worry of falling is concerning for people with PD, as there is potential for negative health consequences. For example, if fear/worry of falling leads to decreased activity, the lower activity could lead to declines in muscle function, physical deconditioning, and other physiologic functions, which could lead to greater risk of falls.[58]

The relatively strong association of VO_2peak with average daily step count is important, as it suggests that maintaining or improving cardiorespiratory fitness might be an effective strategy to maintain healthy levels of ambulatory activity, or that increasing ambulatory activity could improve cardiorespiratory fitness. This is consistent with data from a study examining the general population, which found a link between low physical activity and low cardiorespiratory fitness.[59] There is emerging evidence that exercise training can be used to improve cardiorespiratory fitness in people with PD,[60, 61] although there is not a clear link between exercise training and ambulatory activity in this population. Findings from the longitudinal SPARX parent trial[26] will help elucidate the relationship between cardiorespiratory fitness and ambulatory activity, and the influence of various doses of exercise. Furthermore, given the association of step count with cardiorespiratory fitness, it is

important to determine if there are underlying physiologic changes with PD that compromise overall ambulatory activity very early in the disease process.

Limitations

The final model in this study explained 24% of the variability in daily step count, indicating that further research is needed to examine other factors explaining ambulatory activity in this population. An exclusion criterion for the SPARX trial was engagement in "moderate or vigorous endurance exercise, defined as >2 days/week for at least the past four months." While no participant was excluded during screening based on the exercise criterion, 28.5% of people who were phone screened related that they exercised regularly at a level that produced sweat. In contrast, it is also possible that very sedentary people with PD would not choose to participate in an "exercise study." Thus, the results of this study cannot be generalized to all people with *de novo* PD. Also, depression was an exclusion criterion. No individuals were excluded based on the cut-off of Beck Depression Inventory[29] scores >16, however, it is possible the participants with depression self-identified during the telephone prescreen and were not enrolled. Therefore, the PA level of the sample may have been lowered if depression was not an exclusion criterion.[62] One of the identified factors associated with step count was fear/worry of falling, which was grouped with non-motor symptoms, as it was a patient-reported perception. As such, we were not able to examine the association of actual falls and step count, which should be examined in a future study.[63] Finally, the cross-sectional nature of the study cannot assess causal relationships between daily step count and the associated factors.

CONCLUSIONS

Step count in people with *de novo* PD who were not regular exercisers approached sedentary lifestyle levels. Higher step count was associated with higher cardiorespiratory fitness and no fear/worry of falling. Further study is warranted for elucidating factors that explain ambulatory activity, particularly cardiorespiratory fitness and fear/worry of falling. Clinicians should consider the costs and benefits of interventions such as exercise and activity behavior modification immediately after diagnosis of PD to attenuate the potential adverse health consequences of chronically low ambulatory activity.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Participant Characteristics (mean (SD), unless otherwise stated)

	TOTAL (n = 113)	MEN (n = 63)	WOMEN (n = 50)	p-value
Demographics/Anthropometrics				
Age, y	64.3 (8.6)	64.1 (8.8)	64.5 (8.5)	.815
BMI, kg/m^2	26.9 (4.2)	27.8 (4.1)	25.8 (4.1)	.009 *
Normal (n (%) BMI <25)	43 (38.1)	16 (25.4)	27 (54.0)	
Overweight (n (%) BMI 25-30)	48 (42.5)	35 (54.0)	14 (28.0)	
Obese (n (%) BMI >30)	22 (19.5)	13 (20.6)	9 (18.0)	
Education level				.383
Some High School	3 (2.6)	2 (3.2)	1 (2.0)	
High School Graduate	7 (6.2)	6 (9.5)	1 (2.0)	
Some College / Associate Degree	26 (23.0)	13 (20.6)	13 (26.0)	
College Degree	28 (24.8)	13 (20.6)	15 (30.0)	
Advanced Degree	49 (43.1)	29 (46.0)	20 (40.0)	
PD Disease Characteristics				
Time Since Diagnosis, years	.8 (.9)	.7 (.8)	.8 (1.1)	.802
MDS-UPDRS TD/PIGD Ratio				.020 *
TD (n (%))	92 (81.4)	51 (81.0)	41 (82.0)	
PIGD (n (%))	14 (12.4)	5 (7.9)	9 (18.0)	
Indeterminate (n (%))	7 (6.2)	7 (11.1)	0 (0.0)	
Motor Symptoms				
H&Y Stage (n (%))				.167
H&Y I	29 (25.6)	13 (20.6)	16 (32.0)	
H&Y II	84 (74.3)	50 (79.4)	34 (68.0)	
MDS-UPDRS Motor Experiences (II)	5.5 (3.9)	5.9 (3.8)	5.0 (4.1)	.190
MDS-UPDRS Motor Score (III)	21.1 (8.8)	22.5 (8.9)	19.2 (8.4)	.037 *
Non-Motor Symptoms				
MDS-UPDRS Non-motor (I)	5.3 (3.7)	5.5 (4.0)	4.9 (3.3)	.673
MFIS Total **	16.4 (13.5)	16.5 (14.0)	16.2 (12.8)	.830
MFIS Psychosocial	1.1 (1.5)	1.3 (1.4)	1.0 (1.5)	.134
MFIS Physical **	7.8 (6.5)	7.4 (6.4)	8.4 (6.7)	.444
MFIS Cognitive **	7.4 (6.9)	7.9 (7.5)	6.9 (6.1)	.770
ESS	5.4 (3.7)	5.5 (3.4)	5.2 (4.2)	.468
PDSS-2	9.1 (6.2)	9.3 (6.3)	8.8 (6.1)	.775
Fear/worry of Falling (PDQ-39, Item 9)				.150
Never (n (%))	78 (69.0)	47 (74.6)	31 (62.0)	
Any (n (%))	35 (31.0)	16 (25.4)	19 (38.0)	

	TOTAL (n = 113)	MEN (n = 63)	WOMEN (n = 50)	p-value
Comorbidities				
Total number (count)	5.7 (3.8)	5.6 (3.7)	5.7 (3.9)	.990
Osteoarthritis (n (%))	15 (13.3)	6 (9.5)	9 (18.0)	.187
Cardiovascular Conditions (n (%))	52 (46.0)	31 (49.2)	21 (42.0)	.445
Pulmonary Conditions (n (%))	6 (5.3)	5 (7.9)	1 (2.0)	225
Cardiorespiratory Fitness				
VO_2peak, mL/min/kg	23.5 (5.8)	25.5 (6.3)	20.9 (3.9)	<.001 *

Note: BMI: body mass index; H&Y, Hoehn & Yahr; MDS-UPDRS, Movement Disorder Society-Unified Parkinson Disease Rating Scale; TD/PIGD, Tremor Dominant/Postural Instability Gait Disorder; MFIS, Modified Fatigue Impact Scale; ESS, Epworth Sleepiness Scale; PDSS, Parkinson Disease Sleep Scale; PDQ-39, Parkinson Disease Questionnaire; VO2Peak, peak rate of oxygen consumption during graded treadmill test.

* $p<.05$

** The MFIS subscales were created by summing the items as indicated by the MFIS documentation. Four of the items (18, 19, 20, 21) were erroneously excluded from the tool prior to data collection. For the subscales that required a missing item (physical and cognitive), we took the average of the existing items as the imputed value for the missing item before summing the items to create the subscales. The total MFIS score was calculated by summing the subscales.

Table 2

Physical Activity Descriptive Statistics (n=113)

	Mean (SD)	Median	25th percentile	75th percentile
Average Steps/Day				
Total	5362 (2890)	4564	3401	6983
Weekdays	5573 (3144)	4766	3476	7399
Weekend Days	4692 (2800)	4212	2570	6294
Average Total Activity Count/Day *				
Total	345870 (141796)	316283	249836	425323
Weekdays	353196 (154472)	310139	235680	418947
Weekend Days	321459 (141173)	292739	220025	419036

* Activity count represents the sum of the accelerometer vectors in all three planes and reflects the frequency and intensity of movement, unlike the step count, which reflects steps based on vertical axis acceleration.

Table 3

Regression Results

	Univariate Squared Correlations with Step Count (*p*-value)*	Full Model Squared Semi-partial Correlations (*p*-value)*	Final Model Squared Semi-partial Correlations (*p*-value)*	Direction of Association with Step Count
Demographics/Anthropometrics				
Age	0.09 (0.001)	0.01 (0.206)	-	
BMI	0.00 (0.586)	-	-	
Sex	0.01 (0.243)	-	-	
Education level	0.06 (0.035)	0.04 (0.077)	-	
PD Disease Characteristics				
Time Since Diagnosis	0.03 (0.090)	0.02 (0.061)	0.03 (0.047)	(-)
MDS-UPDRS TD/PIGD Category	0.02 (0.358)	-	-	
Motor Symptoms				
H&Y Score	0.00 (0.920)	-	-	
MDS-UPDRS				
Motor Experiences (II)	0.01 (0.415)	-	-	
Motor Examination (III)	0.08 (0.002)	0.04 (0.017)	0.04 (0.014)	(-)
Non-Motor Symptoms				
MDS-UPDRS				
Non-Motor Experiences (I)	0.01 (0.359)	-	-	
MFIS				
MFIS Psychosocial	0.01 (0.393)	-	-	
MFIS Physical	0.02 (0.116)	-	-	
MFIS Cognitive	0.01 (0.398)	-	-	
ESS	0.03 (0.071)	-	-	
PD Sleep Scale Score	0.00 (0.708)	-	-	
Fear/worry of Falling (#9, PDQ-39)	0.11 (<0.001)	0.04 (0.015)	0.05 (0.005)	(-)
Comorbidities				
Total number	0.00 (0.543)	-	-	
Osteoarthritis	0.06 (0.008)	0.02 (0.117)	-	
Cardiovascular Conditions	0.02 (0.112)	0.02 (0.071)	0.02 (0.050)	(+)
Pulmonary Conditions	0.01 (0.427)	-	-	
Cardiorespiratory Fitness				
VO2 Peak, ml/min/kg	0.16 (<0.001)	0.05 (0.006)	0.10	(+)

Note: BMI: body mass index; H&Y, Hoehn & Yahr; MDS-UPDRS, Movement Disorder Society-Unified Parkinson Disease Rating Scale; TD/PIGD, Tremor Dominant/Postural Instability Gait Disorder; MFIS, Modified Fatigue Impact Scale; ESS, Epworth Sleepiness Scale; PDSS,

Parkinson Disease Sleep Scale; PDQ-39, Parkinson Disease Questionnaire; VO2Peak, peak rate of oxygen consumption during graded treadmill test.

* Variables at $p \leq 0.2$ for univariate and sub-group models were considered for the full model. All variables in the full model were considered for the final model at the start. After the running the backward elimination model, only the variables significant at the $p \leq 0.1$ were selected for the final model.