



Quantifying physical activity in early Parkinson disease using a commercial activity monitor

Sujata Pradhan*, Valerie E. Kelly

Division of Physical Therapy, Department of Rehabilitation Medicine, University of Washington, Seattle, United states

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ABSTRACT

Introduction: Physical inactivity in Parkinson disease (PD) has an impact on motor and non-motor symptoms of the disease. It is unclear whether this decline in physical activity occurs early in the disease, in addition to any decline due to aging, and whether commercial activity monitors can be used to self-monitor physical activity levels in this population.

Objective: To compare the quantity and intensity of physical activity (PA), as measured by commercial activity monitors, in people with mild PD and healthy older adults (HOA). A secondary objective was to assess adherence and user experience with wearing the activity monitoring device.

Methods: An observational descriptive study design examined PA levels over a 14-day period using commercially-available activity monitors (Fitbit Charge HR).

Results: Individuals with PD ($n = 30$) and HOA ($n = 30$) both demonstrated high adherence with wear time (PD = 13.8 [0.5] days, HOA = 13.9 [0.4] days, $p = 0.55$). People with PD took fewer steps per day than HOA (PD = 6416.9 (2795.5), HOA = 11441.3 (3932.1), $p < 0.001$). Compared to HOA, individuals with PD spent fewer minutes per day engaged in moderate to vigorous intensity activity (PD = 33.0 (22.5), HOA = 72.0(37.3), $p < 0.001$) and more minutes per day sedentary (PD = 803.74 (154.9), HOA = 578.26 (103.7), $p < 0.001$). Both groups reported that ease of use and satisfaction with the activity monitor were high.

Conclusions: People with mild PD demonstrated reduced quantity and intensity of PA compared to HOA. Both the PD and the HOA groups had good adherence wearing a commercial activity monitor that provided feedback regarding activity levels.

1. Introduction

Physical activity (PA) is critically important for people with Parkinson disease (PD); however, individuals with mild to moderate PD spend about 75% of their day in sedentary behaviors [1]. To get a holistic estimate of PA throughout the day, continuous monitoring is needed to capture both exercise-related activity and incidental activity that occurs as part of daily life [2].

Given the risks of a sedentary lifestyle for people with PD, promotion of an active lifestyle is recommended in the early stages of PD [4,5]. However, both self-reported [5] and objectively measured [6] estimates of PA suggest that individuals with PD are less physically active than their healthy older counterparts. In addition, most reports indicate the quantity of ambulatory PA in people with PD is lower [1,8] than the popular recommendation of 10,000 steps per day [9,10]. Furthermore, both cross-sectional [7] and longitudinal [11,12] studies demonstrate that the quantity of PA decreases with increasing disease

severity. In addition to lower quantities of PA, research also suggests that the intensity of PA is reduced in those with PD. Individuals with PD spend significant amounts of time in sedentary activities [1,12], suggesting that people with PD may not be reaching the American College of Sports Medicine (ACSM) recommendation for adults to engage in at least 150 min of moderate-intensity exercise each week [12].

Current research examining physical activity includes samples from a spectrum of disease severity ranging from Hoehn and Yahr stages 1–4 [13], but only a limited number of studies have derived estimates from people with mild PD [7,14,15]. Understanding if PA is reduced in the early stages of the disease can inform strategies to mitigate inactivity and increase PA for better symptom management and prevention of functional decline. Knowing PA patterns in early PD is also important to support early referral to rehabilitation services, which is estimated to occur for less than 25% of Medicare beneficiaries with PD [15]. Although most studies do not include healthy older adults (HOA) comparison groups [1,12,15,17], comparing PA in people with early PD and

* Corresponding author.

E-mail address: sujatap@uw.edu (S. Pradhan).

HOA can differentiate between PA declines related to aging rather than the effects of PD.

There is currently a lack of research using commercially-available devices to assess PA quantity and intensity in people with mild PD. Most current studies have used instrumentation designed for research, such as step activity monitors [11,17], actigraphs, or gyroscopes [1,15]. These devices are not accessible to the general public, are expensive, and require substantial post-processing of the data. With exponential growth in the use of commercially-available devices that monitor PA and their widespread use by the general population, we can expect a tremendous increase in patient-reported estimates of their PA. The real-time PA information displayed by these devices may help people with chronic health conditions, including individuals with PD, monitor and increase their PA, possibly leading to improvements in overall health and quality of life. The purpose of our study was to compare the quantity and intensity of PA as measured by a commercial activity monitor in people with mild PD compared to healthy older adults. Secondly, we also examined associations between physical activity and clinical factors to explore preliminary relationships between physical activity and clinical status.

2. Methods

2.1. Study design

An observational descriptive study design was used to examine PA levels over a 14-day period. All study procedures were approved by the local institutional review board. Eligible participants provided signed written informed consent prior to completing any study procedures.

2.2. Participants

Individuals with PD were recruited through the Washington State Parkinson disease registry [28] and flyers distributed at local support groups between 2016 and 2018. A convenience sample of healthy older adults (HOA) was recruited using flyers. Eligibility criteria for all participants were: (1) a score of 26 or greater on the Montreal Cognitive assessment Scale (MoCA); (2) ability to walk a city block without an assistive device; (3) no history of surgery in the past 3 months; (4) no restrictions on daily PA; and (5) no diagnosis of a neurologic condition. An additional eligibility criterion for people with PD was an established diagnosis of PD by a physician. Study size was predetermined based on time and funding resources available.

2.3. Baseline assessment

All participants attended an in-person baseline session for a clinical examination, providing demographic information (age, sex, education level) and a brief medical history, and receipt of the activity monitoring device. Clinical examination included assessment of motor and sensory function, global cognition using the MoCA, and gait, balance, and disease severity. Gait speed was assessed using the 10-m walk test at self-paced and fast speeds using the protocol by Steffen & Seney [18], balance was assessed using the Mini Balance Evaluation Systems Test (MiniBEST) [19], balance confidence was assessed using the Activities-specific Balance Confidence (ABC) Scale [20] and disease severity was assessed using the Movement Disorder Society - Unified Parkinson's Disease Rating Scale (MDS-UPDRS) [21].

2.4. Physical activity monitoring

We used the Fitbit Charge HR (FBHR) [Fitbit Inc.], a wrist-worn monitor with a triaxial accelerometer, to measure the quantity of PA based on the past reports of its use step counts and heart rate measurements in healthy controls [22] and in individuals with PD [23]. Participants were instructed to wear the FBHR device for 14 days and

14 nights continuously except for the time needed to charge the device and during water-related activities.

Adherence with wearing the FBHR was assessed as: (1) the total number of days that the device was worn and (2) the percentage of non-wear time (calculated from missing HR readings). Acceptable adherence was defined as at least 12 days of monitoring and no more than 10% non-wear time per day.

2.5. Quantity of physical activity

The primary measure of PA quantity was the average daily step count, defined as the total number of steps per day averaged over the number of days worn. We also determined the number and percentage of participants in each group that achieved the daily recommendation of 10,000 steps per day [9,10].

2.6. Intensity of physical activity

The intensity of PA was determined by proprietary algorithms (Fitbit Inc.) that define metabolic equivalent (MET) values based on the steps per minute and heart rate activity. Minute-by-minute PA intensity data were defined as: (1) very active minutes (≥ 6 METs); (2) fairly active minutes (3–6 METs), (3) lightly active minutes (1–3 METs), and (4) sedentary minutes.

The primary measure of PA intensity was the average daily number of minutes spent in moderate to vigorous levels of PA, defined as the number of fairly active and very active minutes per day averaged over the number of days worn. These were then expressed as a percentage of the total minutes of their day when they were awake and were wearing the FBHR. We determined the number and percentage of participants in each group that met the weekly ACSM recommendation of moderate or higher intensity exercise for at least 150 min [12].

2.7. Physical activity logs

Participants completed a daily PA log which was used as a quality assurance measure to determine if the participants engaged in activities during periods when the FBHR did not record anything (e.g. water-related activity vs. sitting in one place).

2.8. User experience

Participants rated statements about the ease of FBHR use and the effort required to learn how to use the FBHR on a scale from 1 (hard to use) to 5 (easy to use). For satisfaction, participants rated statements about their satisfaction using the FBHR on a scale from 1 (not at all satisfied) to 5 (very satisfied).

Participants also responded to custom question that asked if the FBHR motivated them to be more active and if so by how much (0–100%).

2.9. Statistical analysis

Descriptive statistics were used to summarize characteristics of each group. Means and estimates of variability were computed for all outcome variables. Data for all variables were examined for outliers, defined as values that were three standard deviations away from the mean. Independent-samples t tests with alpha set at ≤ 0.05 were used to examine differences in quantity of PA, intensity of PA, and adherence with FBHR wear between individuals with PD and HOA.

3. Results

3.1. Participants

A total of 30 individuals with PD and 30 HOA participated. Groups

Table 1
Demographic and clinical characteristics. Values represent mean (standard deviation).

	PD (n = 30)	HOA (n = 30)	P value (95%CI)
Age	68.6 (5.9)	67.3 (4.7)	0.34 (−0.49–1.42)
Sex (M/F)	11/19	9/21	
MoCA	29.2 (0.9)	28.9 (1.9)	0.40 (−0.4–1.0)
Comorbid conditions (#)	1.1 (1.2)	0.9 (1.1)	0.46 (−0.8–0.4)
Years since PD diagnosis	7.8 (5.0)	NA	
Hoehn-Yahr Stage	Stage 1 = 18, Stage 2 = 12	NA	
MDS-UPDRS (total score)	28.5 (16.3)	NA	
MDS-UPDRS (Part III score)	12.9 (10.3)	NA	
Gait speed – self-selected (m/s)	1.5 (0.3)	1.7 (0.3)	0.03 (0.0–0.3)
Gait speed – fastest possible (m/s)	2.2 (0.4)	2.4 (0.3)	0.02 (0.03–0.41)
MiniBEST	23.7 (4.2)	27.0 (1.2)	< 0.001 (1.7–4.9)
ABC	87.4 (15.1)	96.8 (3.3)	0.002 (3.7–15.01)

were similar with respect to age, gender, educational level distribution, and number of comorbidities (Table 1). People with PD and HOA had similar cognitive status based on the MoCA ($p = 0.43$), but people with PD had slower gait speed at both their self-selected pace and their fast pace. Individuals with PD had significantly worse balance and balanced confidence than HOA based on the MiniBEST and ABC scores (Table 1).

3.2. Physical activity monitoring

There were no differences in adherence between the PD and HOA groups. The average number of days the FBHR was worn and the average non-wear time were similar between groups.

The quantity of physical activity was lower in people with PD compared to HOA. Compared to HOA, people with PD took fewer steps per day. Fig. 1 shows the range and variability in the no of steps in each group. Only 4 (13%) individuals with PD compared to 18 (60%) HOA participants walked an average of $\geq 10,000$ steps/day to qualify as physically active individuals.

The intensity of physical activity was also lower for individuals with PD compared to HOA. Individuals with PD spent fewer minutes in moderate to vigorous intensity activity and more minutes sedentary (Table 2). Individuals with PD spent 2.7% (1.9) of their waking time

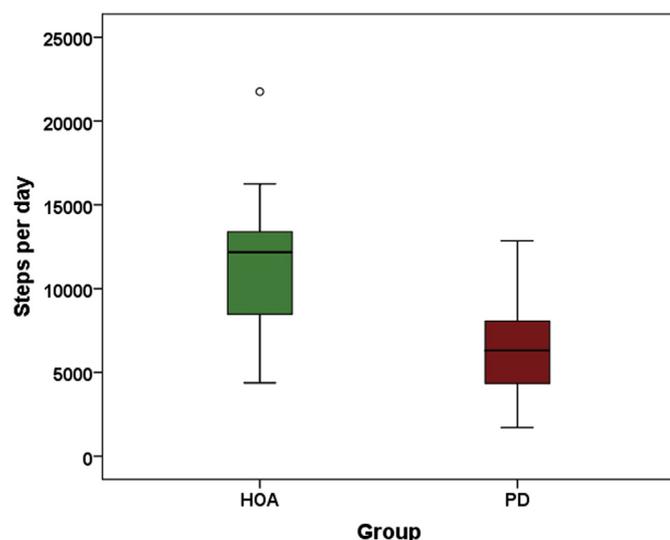


Fig. 1. Quantity of physical activity measured by steps per day for individuals with Parkinson disease and healthy older adults averaged over a 14 day period.

engaged in moderate or higher intensity activity, 17.8% (6.6) of their time in light intensity activities, and 78.9% (7.8) of their day in sedentary behaviors. In contrast, the HOA group spent an average of 6.3% (3.1) of the time engaged in moderate or higher intensity activity, 28.9% (7.3) of their time in light intensity activities, and 63.3% (8.1) of their day in sedentary behaviors. Fig. 2 shows the distribution of the minutes spent in engaging in activities at the different intensities. It is noteworthy that although HOAs spend lesser time in sedentary behaviors compared to PD, the difference in sedentary behavior time is occupied by additional light intensity activity in the HOA group, thus contributing to some of the deficit in reaching the 150 min moderate to vigorous intensity recommendation from the ACSM. Only 15 (50%) of the PD group compared to 26 (87%) HOA met the ACSM recommendation of at least 150 min per week in moderate to vigorous intensity activity.

3.3. Associations between physical activity and clinical status

In the PD group, the no. of steps significantly correlated with gait speed – self-selected ($r = -0.60$, $p < 0.01$) and fastest possible ($r = -0.64$, $p < 0.001$), balance based on the mini BESTest ($r = 0.38$, $p = 0.05$) and the ABC ($r = 0.48$, $p < 0.01$) but not with the MDS-UPDRS-III scores ($r = -0.007$, $p > 0.05$). In the HOA group, the no. of steps did not correlate significantly with the gait or balance measures.

3.4. User experience

Both the PD and the HOA groups rated the FBHR as “easy to use” (PD = 4.3 [0.8], HOA = 4.4 [0.9], $p = 0.61$). Similarly, both groups reported high satisfaction ratings (PD = 4.1 [1.0], HOA = 3.7 [1.1], $p = 0.26$). The proportion of people who reported increased motivation to be active was greater in the PD group (66%) compared to the HOA group (50%), but there was no difference in the perceived increase in activity attributed to wearing the FBHR between groups ($p = 0.97$), and no differences were found for the PA quantity and intensity between people who reported increased motivation compared to those who did not report an increase in motivation in either group (both $p > 0.05$).

4. Discussion

The purpose of this study was to compare the quantity and intensity of total PA in individuals with mild PD and HOA, using a commercially-available activity monitor. Our results indicate that, despite being in the early stages of the disease (based on Hoehn-Yahr stages 1 & 2), individuals with PD were less active than HOA, engaged in lower intensities of activity, and spent significantly greater amounts of time sedentary.

The estimates of PA quantity and intensity demonstrated in this sample are similar to those derived in other samples with mild PD using research instrumentation [15,17]. Research involving people with moderate PD demonstrate that people with PD are about one-third less active than controls [1,6], with a greater proportion of time spent in sedentary or light intensity activities [1,12]. Adding to the existing research, the current study demonstrated that declines in PA quantity and intensity can occur early in the disease and that even individuals with mild PD spend a large proportion of waking time in sedentary behaviors. The inclusion of a HOA group in our study suggests that these declines are not attributable solely to normal aging processes. Estimates of activity levels in the HOA group in our study are somewhat higher than those reported [24] and may have been influenced by selection bias with individuals that are interested in monitoring and improving their activity levels being interested in the study. Visual feedback from the device may have motivated participants to do more than they normally would have, although we did ask if their activity during the participation period was reflective of their usual activity levels and

Table 2
Physical activity quantity and intensity. Numbers represent mean (SD) unless otherwise noted.

Variable	PD Mean (SD)	HOA Mean (SD)	T-test (95%CI)
Quantity of PA			
Total Steps per day	6416.9 (2795.5)	11441.4 (3932.1)	< 0.0001 (3261.1–6787.5)
Number (%) achieving ≥ 10,000 steps/day	4 (13.3)	18 (60.0)	
Intensity of PA			
Moderate or higher activity (minutes/day)	33.0 (22.5)	72.0 (37.3)	< 0.0001 (23.0–54.8)
Light activity (minutes/day)	181.1 (75.7)	260.8 (60.7)	< 0.0001 (44.2–115.1)
Sedentary time (minutes/day)	803.7 (154.9)	578.3 (103.7)	< 0.0001 (–293.6 to –157.3)
Number (%) achieving ≥ 30 min of moderate or higher intensity/day	15 (50.0)	26 (86.7)	

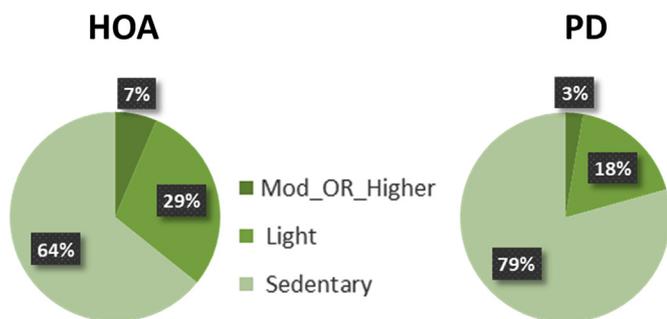


Fig. 2. Physical activity intensity minutes for the waking day in individuals with Parkinson disease and healthy older adults.

participants reported that it was.

There are some important factors and features to consider while selecting an activity monitor. Using devices that measure heart rate in order to provide estimates of intensity of PA is an important consideration when selecting commercial devices since basing physical activity measurement on quantity (steps) alone may not provide a complete picture of one's activity. Non-stepping related activities like yardwork, biking, upper extremity training etc. can only be captured by devices that monitor heart rate and provide an estimate of active minutes. While the FBHR has been reported to provide accurate results at slow walking speeds, there are other devices that may be better suited for higher walking speeds [25]. Also for measuring intensity of activity, The FBHR has been reported to accurately measure steps during aerobic activity and provide heart rate estimates that are similar to the Polar monitor, but it may overestimate steps taken during light intensity physical activity [26]. In individuals with PD where reduced arm swing may be present, alternatives to wrist worn monitors may be considered to get an accurate estimates of activity quantity and intensity. We would like to emphasize that our study only provides results obtained using the Fitbit Charge HR and does not compare its performance experimentally to other devices on the market with similar features. Therefore, our study should be not be viewed as expressing preference of using Fitbit Charge HR over other devices in PD.

The decline in quantity and intensity of physical activity early in the course of PD has significant clinical implications. Decline in PA over time in individuals with PD has been documented, in some instances without a concurrent worsening of motor symptoms or slowing of gait [11]. Although self-selected and fastest possible gait speeds were statistically slower in the PD compared to the HOA group in our sample, they were similar to those reported for age-matched older adults in the literature [27]. Thus, declines in natural ambulatory behavior may precede functional decline, especially during the earliest stages of PD when motor impairment remains relatively mild [11]. Reduced PA quantity and intensity in these individuals with mild PD suggest an urgent need for early referral and intervention to mitigate declining PA and to prevent subsequent functional declines in gait, balance, and motor abilities. The current estimates for utilization of rehabilitation services in the United States are at and 14.2% among Medicare

beneficiaries diagnosed with PD [15]. Until early referral rates to rehabilitation services improve, newly diagnosed individuals with PD need to be self-reliant in preventing PA declines. Real-time feedback provided by commercially-available activity monitors may enable individuals with newly diagnosed PD to take an active role in managing their symptoms through improved PA with remote guidance or a behavioral intervention, as needed.

Limitations of our study include a limited sample size of 30 people per group. Second, it is possible that the estimates of PA reported in this study may include the effect of motivation to be more active, but despite that, these findings suggest that people with PD are significantly less active compared to HOAs. Since our participants had mild PD based on MDS-UPDRS Part III scores, reduced arm swing that could affect step count, a concern with wrist worn monitors, was not a major concern in our sample. Validity of the FBHR activity levels currently determined by proprietary algorithms may need to be established independently in this population.

Adherence as well as usability and satisfaction ratings were very high among participants. Non-wear time was largely accounted for by the time needed to charge the device and intentional removal during water-related activities. Whether participants would continue to wear the device regularly to monitor PA over a longer period of time remains to be determined.

5. Conclusions

This study examined the quantity and intensity of PA using a commercially-available activity monitor in individuals with mild PD compared to HOA. Our data demonstrated that a decline in the quantity and intensity of PA occurs early in the disease process for people with PD and is not explained solely by age-related declines. The use of commercially-available physical activity monitors is on the rise. These monitors are readily available, inexpensive, and provide real-time estimates of PA to users without the need for post-processing of activity data. They are commonly used by adults to track daily physical activity at home and in the community, suggesting the use of a commercially-available activity monitor is socially acceptable. Individuals with PD may be able to use such devices to monitor their physical activity and actively engage in strategies to improve physical activity, possibly mitigating physical and functional declines associated with inactivity.

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