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Daily ambulatory activity levels in idiopathic Parkinson disease

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Abstract—Patients with Parkinson disease (PD) may have decreased physical activity due to motor deficits. We recently validated the reliability of step activity monitors (SAMs) to accurately count steps in PD, and we wished to use them to evaluate the impact of disease severity on home activity levels in PD. Twenty-six subjects with PD (Hoehn and Yahr disease stage 2–4) were recruited to participate in a study of activity levels over 48 hours. Ability to achieve 95% device accuracy was an entry requirement. A Unified Parkinson Disease Rating Scale (UPDRS) evaluation was performed on all subjects, subjects were monitored for 48 hours, and total number of steps per day and maximum steps taken per hour were calculated. Out of 26 subjects, 25 met entry requirements. We calculated the number of steps taken per day, as well as maximal activity levels, and correlated these with UPDRS total score, the activity of daily living subscale, and the UPDRS motor function subscale off and on medication (all $p < 0.01$). Transition from Hoehn and Yahr stage 2 to stage 3 was associated with a decline in functional mobility ($p < 0.005$). A microprocessor-linked SAM accurately counted steps in subjects with PD. The number of steps taken correlated highly with disease severity. SAMs may be useful outcome measures in PD.

Key words: activity level, ambulatory activity, disease progression, gait, home ambulatory monitoring, movement disorders, Parkinson disease, parkinsonism, physical activity, walking.

INTRODUCTION

Despite effective symptomatic therapies for Parkinson disease (PD), function inevitably declines as patients develop gait impairment and postural instability. Many patients adopt a sedentary lifestyle. Recently, prolonged ambulatory monitoring showed that step activity in PD is decreased [1], but data on the relationship between disease severity and functional activity in PD is still lacking. For example, no current studies evaluate the relationship between average daily activity and disease stage in PD, nor do any studies evaluate the relationship between activity levels and severity of symptoms. In part, this deficit in the literature relates to the difficulty of measuring gait in PD, because, in some patients, walking speed, endurance, step length, and cadence may fluctuate according to timing of medications.

Abbreviations: IRB = institutional review board, PD = Parkinson disease, SAM = step activity monitor, SD = standard deviation, UPDRS = Unified Parkinson Disease Rating Scale, VA = Department of Veterans Affairs.

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Typical hip-mounted mechanical pedometers have limited accuracy in subjects with neurological gait impairments, including PD [2]. To measure ambulation in this study, we used a microprocessor-linked step activity monitor (SAM) (Cyma Corporation; Mountlake Terrace, Washington). The capability of the SAM to accurately measure steps has been shown in a number studies that assessed patients with neurological diseases [3–4], including stroke [5–7], muscular dystrophy [8], and multiple sclerosis [2]. We recently showed that the SAM is accurate in measuring Parkinsonian gait [9]. We designed a study to evaluate the relationship between functional ambulation and disease severity in PD. We wished to determine (1) the relationship between Hoehn and Yahr disease stage and ambulation and (2) how disease severity as measured by the Unified Parkinson Disease Rating Scale (UPDRS) correlated with functional ambulation. While Hoehn and Yahr disease stage is a qualitative measure driven in large part by the degree of postural instability of individuals with PD, the UPDRS is a more quantitative evaluation measure that assesses degree of rigidity, tremor, and bradykinesia, as well as postural stability, in individuals with PD.

METHODS

Subjects

Twenty-six individuals meeting the Brain Bank criteria for idiopathic PD [10] were selected either by direct referral from a movement disorders neurologist or by methods approved by the institutional review board (IRB) from a database of patients with PD interested in participating in clinical research. The project was a collaborative study involving patients recruited from the University of Florida Movement Disorders Center and affiliated North Florida/South Georgia Department of Veterans Affairs (VA) Medical Center (n = 21 subjects) or the University of Maryland Movement Disorders Center and the affiliated Baltimore VA Medical Center (n = 5 subjects). Subjects were recruited under separate IRBs at each institution, and informed consent was obtained from all subjects. The patients filled out a demographic questionnaire that included questions on age, sex, height, laterality of onset, and duration of disease.

Evaluations

Clinical UPDRS evaluations were available from the clinical record. All subjects had a full UPDRS evaluation by a trained movement disorders physician. “On medication” UPDRS motor evaluations were available for 24 of the 26 subjects. A “practically defined off” evaluation was available for 21 of 26 subjects. In this case, the term “practically defined off” refers to an examination of motor function, including gait and balance, as well as rigidity, tremor, and bradykinesia that was performed when the patient had not taken medications for at least 12 hours. Although it may take up to 2 weeks in some individuals with PD for the effects of medications to completely wear off, many individuals (particularly those with advancing disease) have a significant increase in symptoms after 12 hours without medication, and this type of evaluation is commonly clinically performed to define medication responsiveness and severity of the underlying unmedicated condition.

Placement of the SAM was performed during a home visit. Physical assessment consisted of having patients perform a 30-foot walk while our examiner recorded time and number of steps without the SAM. The SAM was then calibrated based on the patient’s height and gait, and with the calibrated SAM mounted just over the right lateral malleolus, the patient walked 30 strides. The examiner then read and recalibrated the monitors until they were shown to record steps with an accuracy of at least 95 percent. Patients were instructed to wear the monitor for 2 days, removing it during bathing and during sleep. Mean steps per day were calculated, as well as maximal number of steps per hour. A Mann-Whitney test was performed for a comparison of the number of steps per day and steps per hour in the most active hour among different Hoehn and Yahr stages (**Table 1**, **Figure 1**). The Hoehn and Yahr disease staging system is a qualitative method of judging disease severity. We calculated Spearman correlation coefficients to compare the relationship between UPDRS total and subscales and the two outcome variables of mean number of steps per day and number of steps in the most active hour.

RESULTS

Subject Selection and Demographics

Of the 26 subjects recruited, 25 met the study requirements. One subject was excluded because excessive dyskinesias resulted in inaccurate counting of steps during the home visit. Demographics are displayed in **Table 2**.

Home Activity Levels and Disease Stage

Average measured activity levels decline with disease progression, and individuals with Hoehn and Yahr stage 3 and higher disease had significantly lower activity levels and peak hourly step rates than individuals with Hoehn and Yahr stage 2 or lower ($p = 0.009$). Mean ± standard deviation (SD) daily and maximal hourly activity levels by disease stage are displayed in **Table 1** and **Figure 1**. No differences in age existed between the subjects with Hoehn and Yahr stage 2 (mean ± SD = 70 ± 8) and those with Hoehn and Yahr stage 3 and higher (mean ± SD = 74 ± 10).

Table 1.
Steps per day and peak step rates (mean ± SD) at different Hoehn and Yahr disease stages in Parkinson disease.

Hoehn and Yahr Stage	No. Patients at Stage	Steps/Day	Steps/Hour in Most Active Hour
2	9	5,147 ± 1,903	20.7 ± 9.0
2.5	6	4,087 ± 1,286	12.9 ± 3.9
3/4	9	2,708 ± 1,155*	9.6 ± 4.5*

*Significantly different from Hoehn and Yahr stage 2 ($p < 0.005$).
SD = standard deviation.

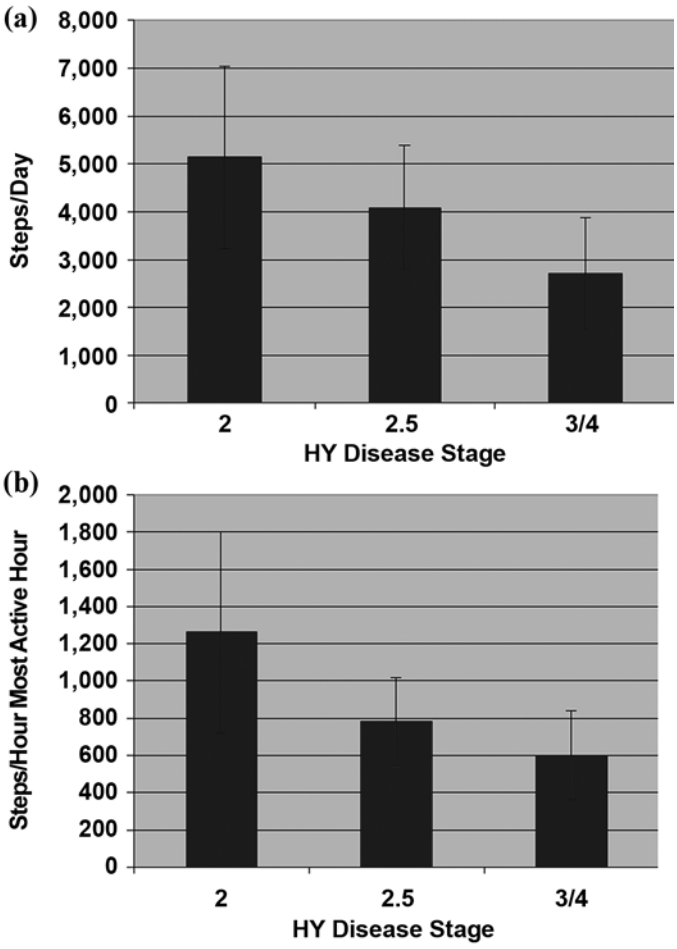

Figure 1.
(a) Steps per day and **(b)** peak step rates at different Hoehn and Yahr (HY) disease stages in Parkinson disease. Error bars denote standard deviation of each sample.

Home Activity Levels and Severity of PD Symptoms

Both mean number of steps per day and mean steps per minute in the most active hour correlated with the total UPDRS score ($r_s = –0.57$ and $r_s = –0.61$, respectively). Examination of the UPDRS subscales showed that the aggregate UPDRS score, combining the clinician motor examination and a patient description of mentation and mood, activities of daily living, and motor complications correlated best with the outcome variables, while individual subscales were less well correlated with the outcome measures. **Table 3** shows the Spearman correlation coefficients between various aspects of the UPDRS and the primary outcome variables, while **Figure 2** shows the relationship graphically.

Subject age in this sample did not independently correlate with mean steps per day ($r_s = –0.26$) or maximal average activity over 60 minutes ($r_s = –0.16$).

DISCUSSION

In our study, we evaluated ambulatory behavior in PD using a microprocessor-linked SAM. We found that number of steps taken per day, as well as average steps per

Table 2.
Subject demographics ($n = 26$). Data presented as mean ± standard deviation or frequency.

Category	Value
Age (yr)	70 ± 9
Sex (M/F)	18/8
Disease-Specific Measures	
Disease Duration (yr)	7.5 ± 3.8
Unified Parkinson Disease Rating Scale	
Total	50 ± 17
Mentation Behavior and Mood (I)	3.1 ± 2.2
Activities of Daily Living (II)	14 ± 6
Motor Examination (III): Off Medication	35 ± 10
Motor Examination (III): On Medication	28 ± 10
Complications of Therapy (IV)	4.0 ± 4.3

F = female, M = male.

Table 3.
Correlation (r_s) of Unified Parkinson Disease Rating Scale (UPDRS) to activity levels.

UPDRS Parameter	*n*	Correlation Between UPDRS and Activity Levels	
		Total Measured Steps/Day	Average Steps/Hour, Most Active Hour
UPDRS: Total (On Medication)	23	–0.47 (p = 0.004)	–0.62 (p = 0.001)
Mood/Cognition (Subscale 1)	25	–0.30	–0.39*
Activities of Daily Living (Subscale 2)	25	–0.48*	–0.40*
Motor Function (Subscale 3): Off Medication	24	–0.45*	–0.36
Motor Function (Subscale 3): On Medication	21	–0.48*	–0.52*
Complications of Therapy (Subscale 4)	25	–0.13	–0.21

*p < 0.05, r_s = Spearman correlation coefficient.

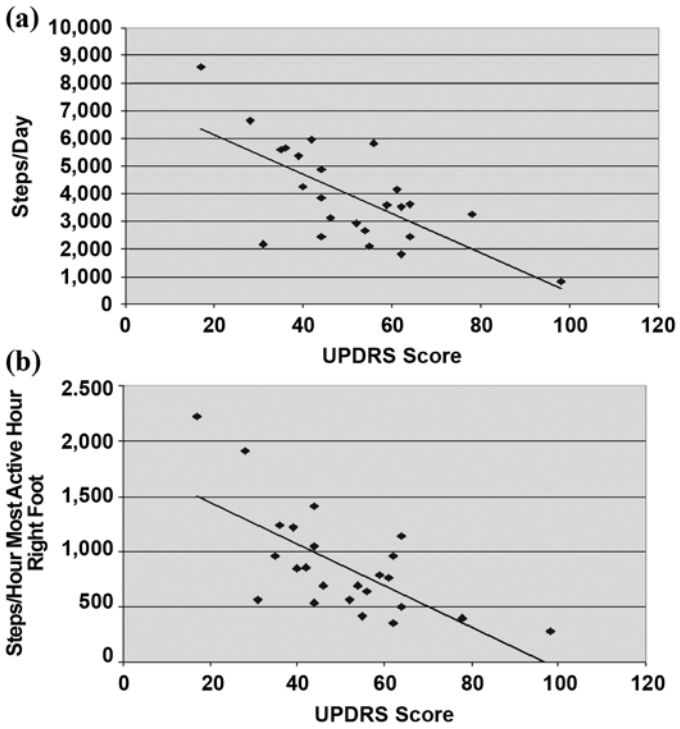

Figure 2.
(a) Steps per day and **(b)** maximal steps/hour during most active hour compared with disease severity (Unified Parkinson Disease Rating Scale [UPDRS] score) in Parkinson disease.

minute in the most active hour were decreased in individuals with more severe PD, as defined by Hoehn and Yahr disease stage. Further, we found that disease severity correlated (as measured by the UPDRS) with both the total number of steps taken during the day and average steps per minute taken during the most active hour as measured by the SAM. Although we do not have patient longitudinal data, the difference in these ambulatory measures in individuals with different disease stages supports the commonly held but untested contention that ambulatory activity declines with disease progression. In particular, transition to Hoehn and Yahr stage 3 disease was associated in our sample with a significant decline in daily activity levels. Individuals with Hoehn and Yahr stage 2 disease and individuals with more significant disease (Hoehn and Yahr stage 2.5 and higher) both have bilateral disease; however, identification of Hoehn and Yahr stage 2.5 and higher is in large part related to increased gait dysfunction and postural instability on clinical examination. This finding therefore supports that onset of increased gait dysfunction and postural instability are associated with decreased functional ambulation. While alterations in gait and balance function are noted early in PD (e.g., in patients with Hoehn and Yahr stage 2 disease) [11], recent studies on the development of disability in PD suggest that transition to clinically significant gait and balance dysfunction, and specifically the transition from Hoehn and Yahr stage 2 to stage 3, is associated with a significant decline in quality of life and capability to perform activities of daily living [12]. Ability to ambulate in this context might be considered another important activity of daily living associated with physical function. In this context, our results add to the literature marking the transition from Hoehn and Yahr stage 2 to stage 3 as a significant functional transition in individuals with PD.

In our recent pilot study of exercise in PD, we noted that participation in an aerobic exercise regimen was associated with significant increase in ability to ambulate in a small number of individuals with PD [13]. While this study suggested that activity levels may be an appropriate target of intervention, home ambulation had not been measured in idiopathic PD in relation to disease stage or severity. Our added results here suggest that home activity

levels can be directly monitored in PD and that measures of home activity levels are related to both disease severity and disease stage.

This study has several limitations. First, although we observed patients for a short time to confirm accurate measurement of gait, we could not observe patients throughout the day to confirm that steps measured by the SAM accurately represented steps taken by the patient. Therefore, although the SAM accurately characterized a variety of gait patterns, we cannot account for the possibility of motor fluctuations within individual patients altering the measurements. Secondly, as noted, we do not have longitudinal information within patients. We therefore have shown that individuals with more advanced disease tend to take fewer steps. Notably, outliers existed in the sample, with some individuals with advanced disease maintaining relatively higher levels of ambulation. This study therefore does not give information about how functional ambulation at home is altered over the course of disease in individual patients or whether subgroups of patients can maintain higher levels of physical activity. Finally, the SAM measures steps taken by subjects, but does not evaluate the size of steps, the speed of movement, or other factors that are altered in PD. As technology advances, further important information may therefore be available regarding home ambulation in PD.

CONCLUSIONS

Our study shows that home activity levels can be directly monitored in PD and the number of steps taken by individuals with PD relates to both disease stage and severity of symptoms as measured by a clinical examination. Our results suggest that increased gait dysfunction and postural instability are associated with decreased functional ambulation. Our study therefore represents an initial study evaluating daily functional walking in PD. Further study will be needed to better characterize functional ambulation in PD. However, this study suggests that measurement of activity levels may serve as a useful and standardizable outcome measure in future studies evaluating the impact of interventions on symptoms and progression in PD.

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The authors have declared that no competing interests exist.

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