

ORIGINAL ARTICLE

Changes in Walking Activity and Endurance Following Rehabilitation for People With Parkinson Disease

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ABSTRACT. White DK, Wagenaar RC, Ellis TD, Tickle-Degnen L. Changes in walking activity and endurance following rehabilitation for people with Parkinson disease. *Arch Phys Med Rehabil* 2009;90:43-50.

Objective: To investigate changes in walking activity and endurance after interdisciplinary rehabilitation in people with Parkinson disease (PD).

Design: Randomized controlled trial.

Setting: Clinic, home, and community.

Participants: Mild to moderate PD (Hoehn and Yahr stage 2-3).

Interventions: Three experimental conditions lasting 6 weeks in duration: (1) no active rehabilitation; (2) 3.0 hours of interdisciplinary rehabilitation a week; or (3) 4.5 hours of interdisciplinary rehabilitation a week. Participants had stable medication regimes during the study.

Main Outcome Measures: Walking activity was estimated with an activity monitor (AM) (time spent walking and number of 10-second walking periods) in the home and community settings over a 24-hour period. Walking endurance was measured in the clinic with the two-minute walk test (2MWT). Linear contrast analyses were applied to examine changes in walking activity and endurance after higher doses of rehabilitation, and 2-way analysis of variance models with interaction were applied to examine the effect of high and low baseline walking levels on changes.

Results: The 2MWT was completed by 108 people with PD (mean age, 66.53y; with PD, 6.59y), and AM data were used from 74 of these people (mean age, 66.7y; with PD, 5.8y). Improvement in AM measures and the 2MWT did not significantly change across increasing dosages of interdisciplinary rehabilitation. Higher doses of rehabilitation resulted in significant improvements in the 2MWT for subjects with low baseline walking endurance ($P=.001$), and in AM measures for subjects with high baseline walking activity ($P<.02$).

Conclusions: Interdisciplinary rehabilitation can improve walking activity and endurance depending on baseline walking levels.

Key Words: Ambulatory monitoring; Parkinson disease; Rehabilitation.

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PARKINSON DISEASE IS A common progressive degenerative movement disorder diagnosed in 1% of the U.S. population over the age of 65, with an annual incidence of 16 to 19 people per 100,000¹ and prevalence of 128 to 187 per 100,000.² People with PD present with neurologic symptoms, such as tremor, rigidity, and bradykinesia.³ These symptoms progress, commonly leading to limitations in walking capacity⁴ and endurance,⁵ as well as sudden stops⁶ and shuffling while walking.⁷ Limitations in walking impact participation in life situations, such as maintaining gainful employment or taking part in recreational activities.^{8,9}

The measurement of walking limitations generally takes place in the laboratory setting and primarily focuses on recording walking characteristics, such as stride length and frequency, and walking performance, such as speed and endurance. Walking activity in the home and community settings is assessed by questionnaires and pedometers. These tools characterize walking activity by estimating the total time spent walking (questionnaires) or by recording the total number of steps taken (pedometer). An accelerometer-based AM also measures walking activity, and provides a more detailed measure by continuously recording walking activities while worn. Recent literature shows that the AM accurately¹⁰ and reliably¹¹ measures the time in seconds a person walks and the number of walking periods lasting at least 10 seconds, which is a noteworthy improvement over questionnaires and pedometers.

Although the rehabilitation literature shows that people with PD improve in walking characteristics and performance after rehabilitation,¹² it is unknown if improvement also occurs in walking activity. A recent study found reduced steps taken in the community in older adults compared with younger counterparts,¹³ and 2 trials report increased steps taken in people with chronic obstructive pulmonary disorder¹⁴ and knee osteoarthritis¹⁵ after intervention. It is also unknown if certain persons with PD benefit more from rehabilitation than do others. Baseline activity appears to be an important predictor of future activity in older adults¹⁶ and

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List of Abbreviations

AM	activity monitor
ANOVA	analysis of variance
CI	confidence intervals
ES	effect sizes
ICC	intraclass correlation coefficient
MCID	minimum clinically important differences
PD	Parkinson disease
2MWT	Two-minute walk test
UPDRS	Unified Parkinson Disease Rating Scale

people with neurologic pathology.^{17,18} Health care providers could better target and prescribe rehabilitation by understanding which types of people with PD benefit most.

The present research study used data from a parent study that investigated the effectiveness of increasing dosages of interdisciplinary rehabilitation for people with PD. Quality of life, activities of daily living, and verbal and nonverbal communication outcome measures were collected in the parent study. The first aim of the present study was to compare changes in walking activity as measured by an AM with changes in walking endurance measured by the 2MWT after interdisciplinary rehabilitation. We hypothesized that a higher dose of rehabilitation would result in improvements in both walking activity and endurance (hypothesis I). The second aim was to investigate whether baseline walking activity and endurance levels modified changes after rehabilitation. We hypothesized that walking levels at baseline would influence changes after rehabilitation (hypothesis II).

METHODS

Subjects

We recruited subjects from Boston Medical Center, the Center for Neurorehabilitation at Sargent College of Health and Rehabilitation Sciences, local neurologists, primary care physicians, and PD support groups in the greater Boston area. Subjects included in the study: (1) had a diagnosis of idiopathic PD, (2) had mild to moderate disease severity (Hoehn and Yahr stage 2 or 3), (3) were 40 years of age or older, (4) had no severe cognitive impairment (<26 on the Mini-Mental Status Examination), (5) did not have substantial depression (<20 on the Geriatric Depression Scale), (6) were on a stable dose of antiparkinsonian medications for 2 weeks prior to and during the course of the study, (7) had received no other form of

physical, speech, or occupational therapy for 2 months prior to the start of study, (8) were able to walk without assistance, (9) were able to understand and communicate with personnel, (10) were able to travel to and from the treatment site, and (11) had no other severe neurologic, cardiopulmonary, or orthopedic disorders that interfered with mobility. Subjects were screened by a neurologist who specializes in movement disorders and a clinical nurse specialist in neurorehabilitation. The present study was approved by the Boston University Institutional Review Board and informed consent was obtained from all participants.

Experimental Design

A statistician blinded to the study’s hypothesis used a block randomization procedure and random number tables generated from a computer-based statistical program^a to assign subjects to 1 of 3 experimental conditions. Condition 1: no active rehabilitation, condition 2: clinic based rehabilitation and a social activity session, or condition 3: clinic and home based rehabilitation (fig 1).

In all conditions a clinical nurse specialist in neurorehabilitation reviewed medication schedules at study entry to ensure an optimal regime, and asked subjects not to change schedules for the duration of the study. Adherence to medication schedules and adverse events were monitored at 3 points in time, initial screening, and 3 and 6 weeks after the start of the study.

Interdisciplinary Rehabilitation Interventions

Clinic based. Subjects in conditions 2 and 3 received 2 weekly 1.5 hour group sessions of interdisciplinary rehabilitation over a 6-week period led by licensed physical, occupational, and speech therapists with expertise in self management for people with PD. Therapists were assisted by 1 or 2 physical and occupational therapy students. Interventions were stan-

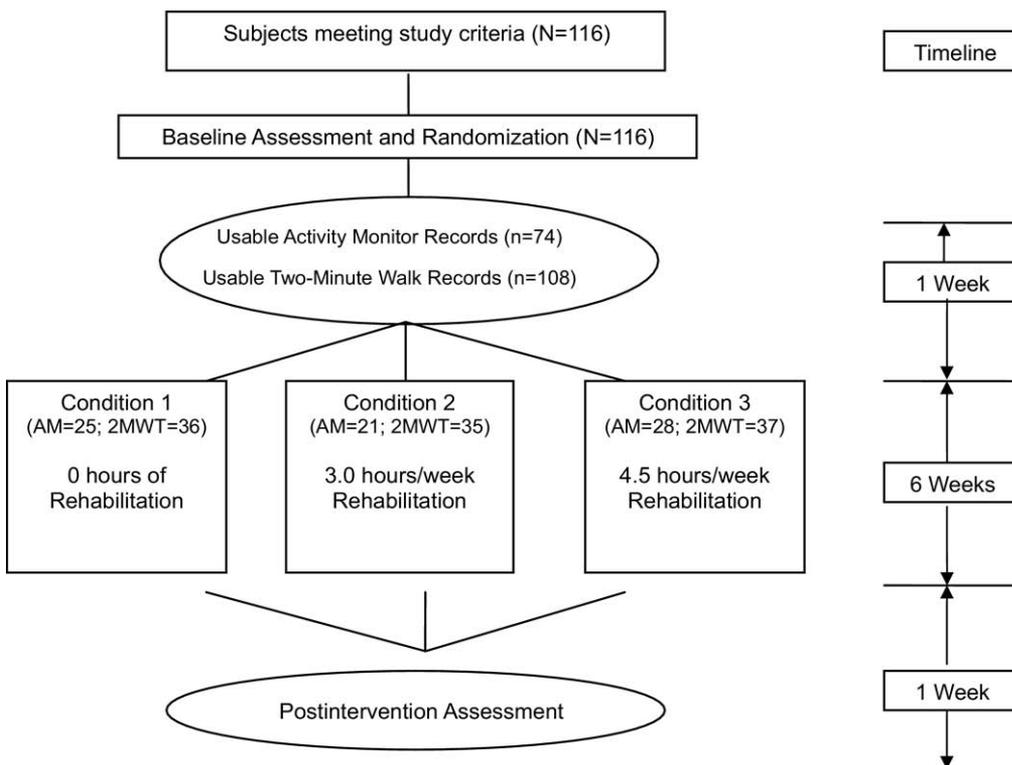


Fig 1. Flow chart and timeline of the study.

standardized with written protocols in leader and participant handbooks. The protocols were based on a self-management approach to rehabilitation. Each clinic based session consisted of: (1) 25 minutes of stretching and strengthening exercises,¹⁹ (2) 10 minutes of speech exercises,²⁰ (3) 15 minutes of functional training, which included bed mobility, transitions between sitting and standing, standing up from the floor, handwriting, swallowing, and communication,²¹ (4) 10 minutes of gait training using auditory cues (metronome and music),²² and (5) 30 minutes of education and training on topics including mobility strategies (eg, walking in the community, navigating in small spaces, and turning strategies), communication strategies (eg, making oneself understood), and self care techniques (eg, maintaining healthy routines). Sessions were carried out at the Center for Neurorehabilitation.

Social activity session. Subjects in condition 2 received a weekly 1.5-hour group social activity session to provide the same number of hours of attention as condition 3. One physical, occupational, or speech therapy student with no knowledge of PD focused these sessions on friendly conversation, discussion of current events, such as the news, weather, and politics, and extracurricular activities unrelated to PD. They provided no physical or self-management intervention. Sessions were carried out at the Center for Neurorehabilitation.

Home based. Subjects in condition 3 received an added weekly 1.5 hour individual session in the home and community settings based on a self-management approach to rehabilitation. One licensed physical or occupational therapist instructed subjects how to incorporate discipline specific compensatory and problem-solving strategies into daily activities, and emphasized the transfer and integration of skills learned in the clinic to the home and community settings.

Outcome Measures

Subjects were assessed at an “on” time (ie, a medication peak) by examiners blinded to the subject’s experimental condition. Outcome measures were taken before and after the 6 week intervention.

Activity monitor. The AM is an ambulatory monitoring instrument that was used for the present study to record the time spent walking and the number of walking periods lasting at least 10 seconds over the course of 24 hours in the home and community settings (fig 2).¹⁰ Walking activity is described as a percentage of time spent walking during the entire time the AM is worn. Walking periods are reported as the number of 10-second walking intervals that occur per hour during the time the AM is worn. A detailed description of how the AM processes accelerometer signals to detect walking activities is described elsewhere.^{10,23}

A recent study found the AM accurately distinguished walking (at both slow and fast velocities) from other activities, such as sitting or standing, in people with PD.¹⁰ High test-retest reliability was found for the time spent walking between 2 consecutive 24-hour periods ($ICC_{2,1}=0.81$), and between two 24-hour periods with 1 and 2 weeks between measures ($ICC_{2,1}$ range, 0.89–0.94),¹¹ indicating that one 24-hour period is adequate to reliably record walking activities in the home and community settings in people with PD. Subjects were asked to wear the AM for 24 hours. Data records that provided at least 75% of 1 day, or 18 hours, were included in the analysis.

The AM was placed on the subject in the clinic by a research assistant, which took no longer than 15 minutes. Subjects were instructed to continue their daily activities as usual. However, they were asked to abstain from showering due to failure of the AM when immersed in water. At the conclusion of each

wearing period, subjects took off the monitor in the home setting and a research assistant retrieved the monitor. The specific function of the AM was not disclosed until the conclusion of the study, to avoid biasing subjects’ walking activity.

2-Minute walk test. The 2MWT is a reliable and sensitive test of walking endurance for people with PD.⁵ The 2MWT is able to detect that people with PD walk less than age-matched controls.⁵ For the present study, subjects were instructed to walk on a flat level surface and “cover as much distance as possible” for 2 minutes. The examiner followed subjects to ensure patient safety and to estimate the distance walked with a digital measuring wheel.^b Subjects performed 2 practice walks and a final third walk,⁵ and were given the option to rest up to 2 minutes after each walking bout.

Statistical Analysis

Descriptive information were reported for subject characteristics (age and sex), and disease severity (ie, years with PD, UPDRS scores, and Hoehn and Yahr stages).

The normality of distribution of dependent and independent variables were confirmed by using the Kolmogorov-Smirnov test. Differences among baseline characteristics between experimental conditions and between included and excluded subjects were evaluated with a 1-way ANOVA for continuous data, and chi-square analysis for categorical data.

To examine if increased doses of rehabilitation resulted in improvements in both AM measures and the 2MWT (see hypothesis I), planned linear contrasts were applied to 1-way ANOVA models with experimental condition as the independent variable. This analysis was conducted for each of the 3 dependent measures: (1) the time spent walking recorded by the AM, (2) the number of 10-second walking periods as recorded by the AM, and (3) the distance walked as recorded by the 2MWT. A linear contrast analysis weights the values of the 3 experimental conditions in the calculation of the F statistic, and is determined a priori to test the hypothesis of increasing improvement from condition 1 to 2 to 3. Condition 1 had no active rehabilitation, thus was weighted as -1 and condition 3 had the most rehabilitation and was weighted 1 .²⁴ The sum of the weights must total zero, thus condition 2 was assigned 0 .²⁴ An F statistic reaching statistical significance indicates greater changes in the dependent variable after larger doses of rehabilitation.

To examine if a person’s level of walking activity and endurance at baseline interacted with changes after increasing doses of rehabilitation (see hypothesis II), 2-way ANOVAs with linear contrasts were applied. Relationships between the independent variables (experimental condition and baseline walking scores for each walking measure) and the 3 dependent variables were analyzed. The baseline score of each walking outcome was coded as low or high using a cutoff score determined by the mean value of each dependent walking variable at baseline. For example, the mean value of all subjects’ 2MWT scores at baseline was used as a cutoff. Those subjects with scores greater than the cutoff were coded as “high endurance” and those with scores less than the cutoff were coded as “low endurance.” This process was repeated using baseline values for the amount of time spent walking and the number of 10-second walking periods. Planned linear contrasts were then applied to both groups to determine if more change in walking activity and endurance occurred within each group with high and low baseline values after increasing dosages of intervention.

For ANOVA models with linear contrasts reaching the level of significance, we calculated ES with Hedges’ g statistics and 95% CI for each pairwise comparison to esti-



Fig 2. AM shown as attached to a subject with and without casual clothing.

mate the difference between experimental conditions.²⁵ The level of significance was set at .05.

RESULTS

One hundred and sixteen subjects participated in the study in 9 groups ranging from 9 to 19 subjects. Of the 116, 10 subjects did not wear the AM for at least 18 hours, 5 refused to wear the AM, 4 AM records were lost, and 23 had sensors that malfunctioned while wearing the AM, resulting with a total of 74 subjects having AM records that were included in the data analysis. The AM was worn for the full 24 hours by 67 of the subjects, and between 18.0 and 23.9 hours by the remaining 7 subjects. For the 2MWT, 2 subjects did not complete all 3 bouts at baseline, 2 did not return for the 6-week visit, 3 did not complete all 3 bouts at the 6-week visit, and 1 subject refused to perform the 2MWT at the 6-week visit, resulting in a total of 108 subjects having 2MWT scores that were included in the data analysis. There were 34 subjects who were excluded from

the AM analysis but included in the 2MWT analysis. These excluded subjects had significantly longer disease durations than the 74 subjects included in the AM analysis ($P=.03$; mean: 8.4 ± 6.5 vs 5.7 ± 4.0 y). No significant differences were observed among subject characteristics between the 3 experimental conditions for AM and 2MWT measures (table 1). Two subjects changed their medication schedules, but were kept in the analyses.

Baseline and 6 week values for the AM and 2MWT measures across all subjects are presented in table 2, and for groups with low and high baseline values in table 3. The analysis across all participants revealed no statistically significant differences in time spent walking or number of walking periods or the 2MWT. However, significant interaction effects for groups with high and low baseline values and experimental condition were found for the time spent walking ($P=.03$) and walking periods ($P=.007$), with a trend toward significance for the 2MWT ($P=.06$). Higher doses of rehabilitation resulted in

Table 1: Characteristics of Subjects Included in AM and 2MWT Analyses Across Experimental Conditions

AM Subject Characteristics (n=74)	Experimental Condition (AM)		
	1	2	3
Number of subjects	25	21	28
Sex (men)	17	15	20
Mean age in years	66.0±8.4	65.6±9.2	68.2±9.8
H & Y; number of subjects			
2.0	15	10	13
2.5	5	8	12
3.0	5	3	3
Mean years with PD	5.6±3.5	5.1±4.1	6.5±4.3
Mean total UPDRS at baseline	20.7±10.4	27.4±9.7	23.0±8.6

2MWT Subject Characteristics (n=108)	Experimental Condition (2MWT)		
	1	2	3
Number of subjects	36	35	37
Sex (men)	24	23	27
Mean age in years	65.4±8.2	65.9±8.2	68.1±10.3
H & Y; number of subjects			
2.0	19	16	20
2.5	10	15	12
3.0	6	4	4
Mean years with PD	6.7±5.6	6.9±5.2	6.1±4.3
Mean total UPDRS at baseline	35.8±13.5	41.1±11.6	36.6±10.8

NOTE. Values are mean ± SD.
Abbreviation: H & Y, Hoehn and Yahr.

significant improvements in the 2MWT ($P=.001$) for subjects with low baseline walking endurance. Significant improvements were found for the time spent walking ($P=.016$) for subjects with high baseline walking times, and for walking periods ($P=.007$) for subjects with high baseline walking periods (fig 3). Only subjects with a high number of walking periods at baseline showed a significant moderate to large ES between conditions 1 and 3, 0.94 (95% CI, 0.07–1.81).

DISCUSSION

The purpose of the present study was to compare changes in walking activity measured in the home and community settings with walking endurance measured in the clinic after interdisciplinary rehabilitation in people with PD. Though changes in both walking activity and endurance did not reach the level of statistical significance after increasing dosages of interdisciplinary rehabilitation, higher doses did result in significant improvement in the 2MWT ($P=.001$) for subjects with low baseline walking endurance levels, and improvement in walking activity ($P=.01-.02$) for subjects with high baseline walking activity levels. Although changes in walking in the home and community settings were not found to be robust across all

subjects, the general approach and findings of the present study are novel and noteworthy. To date, this is the first study to examine changes in walking activity in the home and community settings with an AM after rehabilitation in people with PD. In addition, the results of the present study suggest that baseline levels of walking activity and endurance influence changes after rehabilitation.

Absence of improvements in walking activity and endurance could be due to the limited intervention time that was devoted to walking. Treatment applied in the parent study targeted multiple body functions and activities from a variety of rehabilitation specialties (ie, physical, occupational, and speech therapy). Participants in condition 2 spent a total of 2 hours over 6 weeks working on improving walking ability, whereas those in condition 3 spent 3 hours. Both the restricted total time with walking specific intervention and small difference in walking treatment time may have limited our ability to detect differences between conditions.

Other possible reasons for the absence of improvement in the total group were the subjects' mild disease severity and fast baseline walking speed. Over 85% of the study participants had mild disease as measured by Hoehn and Yahr (2 or 2.5) stages,

Table 2: Outcome Measure Values at Baseline and Postintervention for the 2MWT, Time Spent Walking, and 10-Second Walking Periods Across Each Experimental Condition

Experimental Condition	Baseline			Postintervention		
	2MWT (n=108) (m)	Time Spent Walking (n=74) (%)	10-Second Walking Periods (n=74) (no./h)	2MWT (n=108) (m)	Time Spent Walking (n=74) (%)	10-Second Walking Periods (n=74) (no./h)
1	173.0±45.1	6.6±3.5	6.3±3.0	175.5±54.5	6.2±2.4	6.2±2.3
2	163.0±29.3	6.0±2.7	5.6±2.6	170.5±31.0	6.0±2.5	5.8±2.7
3	162.2±38.4	5.8±2.8	5.4±2.4	171.4±31.7	5.9±2.7	5.7±2.8

NOTE. Values are mean ± SD.

Table 3: Baseline and Postintervention Values for the 2MWT, Walking, and Number of 10-Second Walking Periods Within Each Experimental Condition for Subjects Above and Below Mean Baseline Values

2MWT (m)	Experimental Condition	n	Baseline	Postintervention
			Mean \pm SD	Mean \pm SD
Below baseline mean of 166.1m	1	17	137.8 \pm 21.0	137.3 \pm 34.0
	2	19	143.0 \pm 22.7	150.0 \pm 24.1
	3	20	135.7 \pm 27.9	152.0 \pm 25.9
Above baseline mean of 166.1m	1	19	204.5 \pm 36.6	209.7 \pm 46.1
	2	16	186.7 \pm 14.9	194.9 \pm 17.6
	3	17	193.5 \pm 21.8	194.2 \pm 21.1

Walking (% of time)	Experimental Condition	n	Baseline	Postintervention
			Mean \pm SD	Mean \pm SD
Below baseline mean of 6.16%	1	14	3.9 \pm 0.8	4.7 \pm 1.7
	2	12	4.3 \pm 1.1	5.1 \pm 1.7
	3	18	4.6 \pm 1.0	4.7 \pm 2.0
Above baseline mean of 6.16%	1	11	10.1 \pm 2.0	8.2 \pm 1.5
	2	9	8.3 \pm 2.4	7.1 \pm 3.0
	3	10	8.0 \pm 1.7	8.0 \pm 2.4

10-Second Walking Periods (no./h)	Experimental Condition	n	Baseline	Postintervention
			Mean \pm SD	Mean \pm SD
Below baseline mean of 5.76 bouts/h	1	14	4.0 \pm 0.8	4.9 \pm 1.7
	2	15	4.4 \pm 0.9	5.1 \pm 1.7
	3	16	4.5 \pm 1.0	4.3 \pm 1.4
Above baseline mean of 5.76 bouts/h	1	11	9.2 \pm 2.2	7.9 \pm 1.9
	2	6	8.5 \pm 3.3	7.5 \pm 4.2
	3	12	6.8 \pm 1.0	7.7 \pm 3.1

Abbreviation: walking, duration of time spent walking.

and many subjects already walked close to an age adjusted maximum walking speed at the start of the study, suggesting a possible ceiling effect of the 2MWT. Oberg et al²⁶ found that healthy older adults walk with a fast speed between 1.4 and 1.6m a second. For subjects in the high baseline 2MWT group, 22 of 52 subjects walked greater than or equal to 1.6 meters a second at baseline, although none of the 56 subjects in the low group initially walked at this speed. This may account for the significant improvements in the low baseline 2MWT group but not in the high baseline group. A longer timed walking test, such as the 6- or 12-minute walk test, might have been more responsive to changes in walking endurance after rehabilitation.

Improvements in the AM measures occurred only in those people with high baseline walking activity. It may be that a sufficient walking endurance is a prerequisite to increases in walking activity. A critical level of endurance may need to be exceeded before increases in walking activity in the community can occur. Future study is needed to further investigate this hypothesis. The results in the present study are also consistent with findings in the literature suggesting that a person's baseline level of activity impacts future activity.^{12,17,18,27-35}

A limitation of the present study is the high number of AM records that were not usable due to malfunction of the AM sensors. Malfunction of the sensor was most commonly due to a broken connection to the accelerometer, or to the accelerometer sensor becoming detached. Subjects included in the 2MWT analysis (n=108) but not the AM analysis (n=74) had a longer disease duration on average than those included in

both analyses (8.4 \pm 6.5 vs 5.7 \pm 4.0y). People with more disease severity (ie, longer disease duration and higher UPDRS scores) were under-represented in the AM analysis compared with the 2MWT analysis. The feasibility of using the AM in subjects with more advanced disease may be limited given the size of the AM data logger and the 24 hours we asked subjects to wear the monitor. In addition, the results could have been influenced by differences between AM and 2MWT groups; however, we conducted our analyses for the 2MWT using the same 74 subjects and found similar results.

Although the AM has been shown to accurately¹⁰ and reliably¹¹ record functional activities, the impact of wearing the AM on daily functional activity has yet to be investigated in people with PD. Subjects in previous studies have reported changing planned activities due to wearing the monitor,³⁶ and the absence of improvements in the present study could have been due to the same reason.

Despite these limitations, the results of the present study suggest that interdisciplinary rehabilitation does improve walking activity and endurance in people with PD when baseline walking activity and endurance is considered. The literature has no estimates for MCID for walking activity and endurance; however, estimates based on similar outcomes in people with stroke suggest a 10% gain over baseline values as an estimate of MCID.³⁷ Subjects with 2MWT scores below the mean at baseline who received the highest dose of rehabilitation had a 12% increase in the 2MWT, 135.7 \pm 27.9m to 152.0 \pm 25.9m (see table 3). Changes in AM measures did not improve more than 10% overall. These findings are clinically relevant given

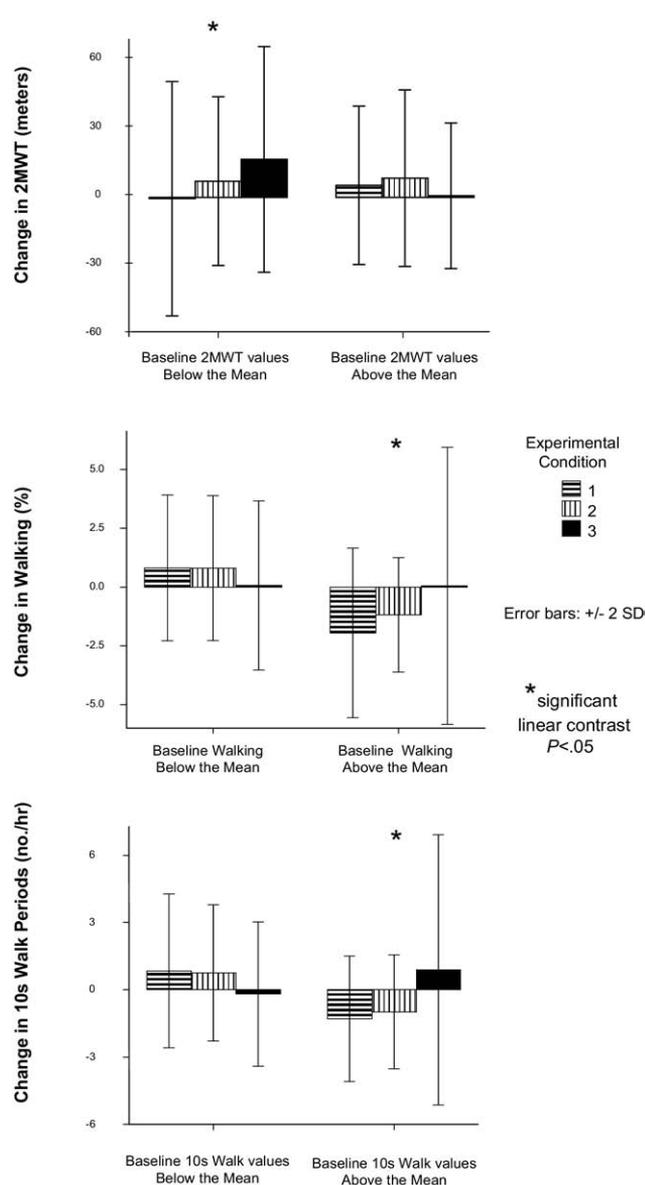


Fig 3. Changes in walking activity and endurance stratified by mean baseline walking values.

that PD is a progressive disease with subsequent limitations in walking.⁴⁻⁷ Although the present study findings are not robust, they are promising to decelerate progressive declines in walking activity and endurance. In addition, clinicians may consider emphasizing walking activity or endurance during rehabilitation based on baseline levels of walking in people with PD.

Future study is needed to confirm if changes in walking activity occur after rehabilitation in people with PD and if the AM is a feasible, responsive measurement tool capable of capturing changes in walking activity. Though significant linear trends were found for AM measures in subjects with high baseline walking values, ESs between experimental conditions did not reach the level of significance. In addition, future studies should investigate if declines in walking activity and endurance can be attenuated with rehabilitation over the long term. Future research should explore the usefulness of the use

of emerging technologies to measure walking activity. As technology advances, added research questions can be asked. For instance, future monitors will soon be able to detect the geographic context where activities occurred (eg, walking in the community vs at home),³⁸ and to identify neurologic symptoms specific to PD, such as tremor, bradykinesia, and freezing or festinating gait.³⁹ These tools can be used to investigate changes in walking activity across different community environments, and how the presence of neurologic symptoms varies with functional activity outside of the clinic.

CONCLUSIONS

Although we did not observe improvements in walking activity and endurance across all subjects, significant improvement did occur when a person's baseline level of walking activity and endurance was considered. People with PD with high walking activity at baseline made improvements in amounts of walking with increasing doses of rehabilitation, and those with low walking endurance at baseline made significant improvements in walking endurance. Future research is needed to replicate these results and further investigate changes in walking activity outside of the clinic after rehabilitation in people with PD.

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