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Original Article

Post-Physical Therapy 4-Month In-Home Dynamic Standing Protocol Maintains Physical Therapy Gains and Improves Mobility, Balance Confidence, Fear of Falling and Quality of Life in Parkinson's Disease: A Randomized Controlled Examiner-Blinded Feasibility Clinical Trial

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Abstract

Objective: Parkinson's patients will experience mobility disturbances with disease progression. Beneficial effects of physical therapy are short-lasting. Novel interventions are needed to maintain these benefits. **Methods**: Fourteen Parkinson's patients (71±4.08 years) participated in a randomized controlled examiner-blinded feasibility clinical trial. After 12 physical therapy sessions, the intervention group received a height-adjustable desk that facilitates stepping while standing, for 4 months. Explorative outcome measures included MDS-UPDRS II, III, TUG, 8.5m walking test, PDQ-39, sABC, sFES, DEXA scans, and lower extremity strength. **Results**: Post-physical-therapy, everyone significantly improved on the MDS-UPDRS II, III, TUG, and 8.5m walking test, and PDQ-39. ($p<0.05$) After 4 months, the control group regressed towards pre-physical-therapy values. In the intervention group, sedentary behavior decreased beyond desk use, indicating a carry-over effect. MDS-UPDRS II, PDQ-39, sFES, sABC, TUG, 8.5m walking test, activity time, sitting time, hip strength all improved with clinically relevant effect sizes. **Conclusion**: Post-physical therapy in-home reduction of sedentary behavior was associated with maintenance of physical benefits and additional improvements in mobility, activity time, balance and quality of life.

Keywords: Parkinson's Disease, Physical Therapy, Sedentarism, Sarcopenia, Quality of Life

Nicolaas I. Bohnen is part of an academic start-up (together with Miriam van Emde Boas) that has licensed the technology to pursue medical pathway regulatory approval. The remaining authors have nothing to declare.

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Figure 1. Image of the Height adjustable instrumental Activities of daily living Moving Desk.

Introduction

Axial motor dysfunctions in Parkinson Disease (PD), which are least responsive to dopaminergic therapy, incline many patients towards a sedentary lifestyle and place them at increased risk for the negative consequences of physical inactivity[1–3]. When people with PD (PwPD) develop postural imbalance and gait difficulties (PIGD), they are generally referred to physical therapy (PT) for management of their mobility difficulties, but while the immediate benefit of this intervention is not disputed, there is disagreement about the frequency, intensity and duration as well as how long the benefits last[4]. Despite these conflicting findings, there seems to be a growing consensus that for PwPD, for any physical activity or physical exercise program to have positive lasting effects, there needs to be a long term commitment whether in the form of supervised PT or less supervised/group programs[5–8] of which there are an abundance of programs offered in the community for PwPD. Recently, however, there is an increasing awareness, driven by a body of evidence, that focusing on participating in physical exercise programs alone is not enough. In addition, there needs to be an effort as well to decrease the amount of time spent sitting, reclining, or lying down, also known as sedentary time or sedentary behavior, during the many remaining hours of the day that we are not physically active[9–11]. Recent studies indicate that regardless of exercise, too much sedentary behavior is linked to major disability in the elderly[12]. There is compelling evidence that too much sedentary time can result in a myriad of diseases, causing some to conclude that too much sitting should be considered a health hazard[13]. While early in the disease there is no difference in level of activity compared to age controlled peers, later on in the disease self-reported physical activity declines[14] and PwPD are found to be about 33% more sedentary as their age-controlled peers[2]. There is evidence that this has a compounding negative effect on PD symptoms, mobility and QoL[15]. Hence, there needs to be additional, equal attention towards decreasing sedentary behavior[16] or more precisely, replacing sedentary behavior with physical activity[17,18]. There is a need to optimize mobility functions and maintain the gains made in PT (an unmet need at this time) but also to decrease sedentary behavior in PD patients with PIGD (another unmet need). PwPD need strategies that allow them to be physically active during their regular daily activities.

To address all these unmet needs, we developed a novel intervention called the “Height adjustable Instrumental Activities of daily living Move Desk” (“HiAMD”) Standing behind this desk is enhanced by cueing the user to make regular sideway steps. The HiAMD can be easily integrated with regular desktop activities (iADL) in the patient’s home, thus circumventing many of the physical and time traditional barriers for PwPD[19,20]. Figure 1 shows an image of the HiAMD. Using the HiAMD means physical activity is promoted while incorporated with routine desktop activities.

The aim of this feasibility study was to investigate the HiAMD as a post-PT in-home intervention, replacing sedentary behavior with physical activity in PwPD with PIGD. The main hypothesis was that the in-home intervention facilitating a decrease in sedentary behavior, in addition to the standard care with its focus on increasing physical activity (i.e., weekly physical exercise group) would be more effective in maintaining the improvements made in PT than the current standard care alone. Exploratory outcome measures used were the MDS-UPDRS II, III, TUG, and 8.5m walking test as well as measures of sarcopenia and frailty as measured in hip muscle groups strength and DEXA scans. Secondary exploratory outcome measures were related to QoL, balance, FoF and activity time. Participants were tested before PT (Visit 1/V1), after PT (Visit 2/V2) and after the 4 months of home intervention (Visit 3/V3).

Materials and Methods

Participants

PwPD who sought medical care at the University of Michigan were included. Inclusion/exclusion criteria were as follows:

Inclusion criteria:

1. ≥ 45 years (M/F).
2. PD diagnosis following the UK Parkinson's Disease Society Brain Bank Research Center clinical diagnostic criteria for PD, consistent with the typical nigrostriatal denervation pattern on VMAT2.
3. Hoehn and Yahr stages 2-4 and/or presence of PIGD, such as history of (near) falls, slow gait, and/or freezing of gait.
4. Able to place the HiAMD in their home and spend at least 2 hours per day doing desktop activities.

Exclusion criteria:

1. Inability to stand or walk without an assistive device.
2. History of symptoms in stance that preclude safe and comfortable participation.
3. History of significant symptomatic cardiovascular or pulmonary disease.
4. History of active symptomatic rheumatoid arthritis.
5. History of stroke or other focal brain conditions with residual sensorimotor deficits interfering with stance functions.

Intervention vs Control and Outcome Measures

The study was conducted as an examiner-blinded, randomized-controlled clinical feasibility trial. Participants were randomized into two groups by a statistician. After 12 sessions of PT, Group 1 (control) received standard care only with its focus on increasing physical activity defined as a weekly physical exercise group). Group 2 (experimental) received the in-home HiAMD in addition to standard care. Demographic information, levodopa equivalent dose (LED), duration of disease, (only at V1), clinical data, Movement Disorder Society-Unified Parkinson's Disease Rating Scale (MDS-UPDRS II and III), gait velocity, short Activity-specific Balance Confidence (sABC) scale, short Fall Efficacy scale, (sFES), activity time, and Parkinson's Disease Questionnaire (PDQ-39) were collected during V1-V3, as well as comprehensive, whole-body composition scans using dual-energy X-ray absorptiometry (DXA) Hologic Discovery W (Hologic Inc.). This included measurements of whole body lean and adipose mass (g), as well as BMD (g/cm^2) for the lumbar spine and femoral neck. Hip abduction and adduction

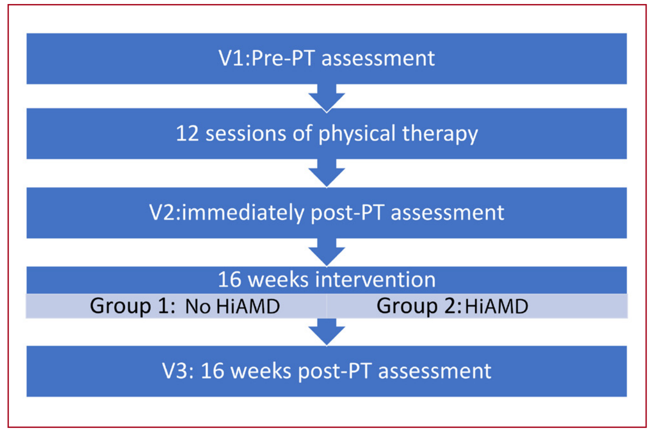

Figure 2. Flowchart of the study.

muscle strength were assessed with the MicroFET2™ MMT (Figure 2).

12 PT sessions. Based on an evidenced based literature review[21], participants received 12 individual, PD-specialized PT sessions (2-3 times/ week over a period or 4-6 weeks). Sessions lasted 45 minutes and the specific nature of the PIGD motor features in the individual were evaluated and treated. The PT sessions, provided by PTs with extensive experience treating PwPD with PIGD motor features, represented the best PT management for PwPD in the community. Every participant was given a comprehensive PT evaluation. Personalized long term and short-term goals were set in consultation with the participant to ensure these goals were functional, measurable, attainable and salient to optimize motivation and compliance. Examples of these goals are: able to roll over in bed independently; able to maintain dynamic balance (walking) while participating in double task (holding glass with water) for 8.5 meters; able to get out of bed (low surface) independently. After each session the progress on each goal was documented. The PT sessions were not "identical"; however, they were all based on the needs of the individual participant and people were treated with the same approach for learning new skills and to increase range of motion, strength, balance or endurance. All participants made functional gains measured by gold standard tests after completions of the PT sessions (See "Results").

Weekly exercise classes during the 16-week post-PT controlled trial for both groups

Both groups participated in an adapted version of the Delay the Disease program for PD[22], consisting of weekly group sessions in the community during the 16-week post-PT period. These sessions included 60 minutes of physical exercise aimed at improving range of motion and strength combined with gait and balance exercises. Participants were required to attend at least 50% of

	All PD (n=14)	No HiAMD (n=8)	HiAMD (n=6)
	Mean +/- SD	Mean +/- SD	Mean +/- SD
Age (yrs)	71±4.08	69.63±3.11	72.83±4.75
Gender (M/F)	13/1	7/1	6/0
Disease duration (yrs)	8.39±5.55	10.63±6.28	5.42±2.54
Median H&Y	2.50	2.50	2.75
LEDD (mg)	718.46±328.81	740±357.25	693.33±323.91

Table 1. Demographics.

	Within Group Visit 1 vs Visit 2 Total Cohort (n=14)								
	Visit 1		Visit 2		t	P-value <0.05	ES 0.35-5.00 or more Cohen's	95% C I	
	Mean	SD	Mean	SD				Lower	Upper
MDS-UPDRS II	14.00	9.80	11.77	8.79	1.66	0.062	**0.46**	-0.12	1.02
MDS-UPDRS III	43.23	11.86	37.96	11.23	3.53	**0.002**	**1.02**	0.30	1.71
PDQ-39	22.70	17.26	18.50	10.32	1.39	0.096	**0.40**	-0.20	0.98
sFES	12.00	4.83	11.14	2.96	0.94	0.184	0.26	-0.30	0.81
sABC	50.36	22.98	49.64	25.15	0.20	0.424	0.05	-0.47	0.58
TuG (s)	10.03	2.64	9.03	2.99	2.76	**0.008**	**0.74**	0.13	1.32
8.5m walking (s)	8.51	2.45	7.50	1.90	3.39	**0.002**	**0.90**	0.27	1.52
Moderate Intensity Activity (hrs/wk)	4.30	5.57	4.09	3.78	0.13	0.451	0.03	-0.49	0.56
Sitting time (hrs/wk)	53.75	24.73	52.50	25.54	0.27	0.397	0.07	-0.45	0.59
Hip abductor strength (lbs)	21.87	9.27	21.73	8.40	0.09	0.465	0.02	-0.52	0.57
Hip adductor strength (lbs)	24.09	9.12	26.08	7.82	-1.76	0.052	**-0.49**	-1.05	0.10
ALM (kg)	18.74	2.94	18.90	2.80	-0.70	0.248	-0.19	-0.71	0.35
ALMI (kg/m^2)	8.07	1.27	7.98	1.12	0.71	0.245	0.19	-0.34	0.72
leg lean mass (kg)	11.17	2.50	10.96	2.16	1.50	0.079	**0.40**	-0.15	0.94
trunk lean mass (kg)	28.83	6.64	28.79	6.54	0.16	0.438	0.04	-0.48	0.57
T-score of total lumbar BMD	1.05	0.19	1.05	0.18	-0.18	0.432	-0.05	-0.62	0.52
T-score of hip BMD	0.74	0.11	0.73	0.13	1.16	0.134	**0.31**	-0.23	0.84

Table 2. Within Group Visit 1 vs Visit 2 Total Cohort.

these sessions. Current standard of care for PwPD strongly advises participation in exercise programs in the community[5-7].

HiAMD. The intervention group received the HiAMD in their homes. The proprietary technology enhances standing with stepping, by facilitating the user to take regular, lateral steps without interference of activities. The added function of weight shifting decreases stress on the musculoskeletal system and may also aid step initiation and postural control, two major impairments associated with PD. The HiAMD also provides support, possibly reducing fear of falling (FoF), which is associated with poor functional abilities and reduced QoL in PwPD[23,24]. participants were instructed to use the desk at libitum, for a total of 2 hours a day (accumulatively not continuously) 5 days a week. Use of the HiAMD was manually logged.

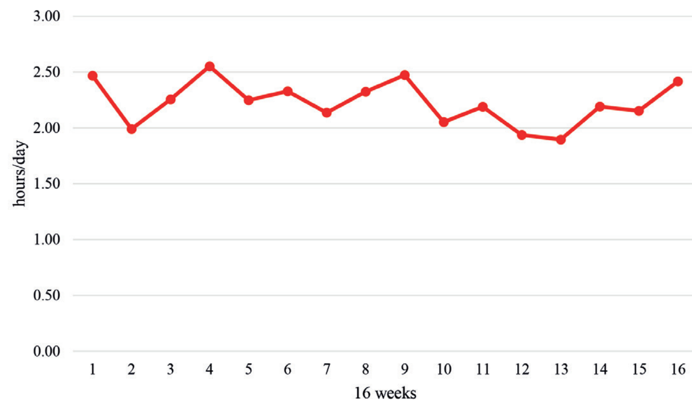

Figure 3. HiAMD utilization during 16-wk intervention.

Statistical analysis

We compared groups using the Chi-square test for categorical data. For continuous variables, the paired t-test was used for within group comparison and the independent t-test for between group comparison. While we looked at significance ($p<0.05$), we put greater emphasis on the Effect Size in this feasibility trial. Effect Size was calculated to determine the minimally clinically important difference (MCID set at 0.3-0.5). Angst et al[25] indicated that MCID raised the importance of outcome effects beyond the statistical level. Statistical analyses were performed using SPSS (version 29) statistical software.

Results

Twenty-six participants were initially enrolled: One had to be withdrawn due to medical reasons, 2 withdrew because of personal reasons, and 2 could not participate because the study was discontinued. Thus, 21 participants enrolled at V1. Further attrition caused 19 to remain at V2 and 14 to complete the study. Of these 14 participants, 6 were randomized in the HiAMD group and 8 in the control group. Participant characteristics are summarized in Table 1.

Baseline vs 12 PT sessions: V1 vs V2

After 12 individual PT sessions, all participants significantly improved on the MDS-UPDRS III, TUG, and 8.5m walking test ($p<0.05$). PDQ-39, MDS- UPDRS II and Hip Adductor strength (almost significant) reaching the MCID (0.3-0.5). Other outcome measures did not reach significance or MCID. Importantly, when the intervention and control group are separated, the primary outcomes of the MDS-UPDRS III and 8.5m walking test remain significant.

16-week post-PT intervention: V2 vs V3

The average use of the HiAMD was 2.2±0.4 hours per day for 5 days per week. Excellent and sustained compliance was self-reported during the 4-month intervention. The participants were able to perform any activity that they normally would do sitting behind their desk, now standing and sidestepping/weight shifting. They reported watching movies, using the computer, completing puzzles, writing, cutting vegetables and folding laundry (Figure 3).

Within group comparison showed that, The MDS-UPDRS II did not reach a significant change or the MCID in the control group but reached the MCID in the intervention group. Both Groups regressed on their MDS-UPDRS III score reaching significance in the control group and an Effect Size twice as much in the control group as the intervention group. PDQ-39 reached MCID in the intervention group and regressed in the control group, not reaching the MCID or significance. The sFES did not reach significance or the MCID in this analysis. In the control group the sABC, TUG, 8.5m walking test, and moderate intensity activity regressed toward pre-PT-intervention values. TUG regressed significantly and all four tests reached the MCID. In the intervention group, no difference was found between V2-V3 for the TUG and the 8.5m walking test. sABC, and activity time improved and reached the MCID. Sitting time in the control group and intervention group both decreased reaching the MCID, but the decreased sitting time in the intervention group was almost 2 times higher compared to the control group. Hip abductor strength significantly improved in the control group and nearly significantly improved in the intervention group. However, the percentage of hip abductor strength improvement was more than twice as high in the intervention group compared to the control group, both reaching the MCID. Hip adductor strength was significantly improved in the intervention group and regressed in the control group without reaching MCID. Finally, Appendicular Lean Mass Index (ALMI), leg lean mass, and T-score of total lumbar BMD and hip BMD, also reached the MCID in the intervention group but not in the control group (Table 4).

When we compared the change between visit 2 and 3,

Table 3. Within Group Visit 1 vs Visit 2 Intervention & Control Group.

	No HiAMD (n=8)									
	Visit 1		Visit 2		% diff	t	P-value <0.05	ES 0.35-5.00 or more Cohen's	95% CI	
	Mean	SD	Mean	SD					Lower	Upper
MDS-UPDRS II	13.75	10.73	10.88	8.98	-20.91	1.24	0.127	0.44	-0.30	1.16
MDS-UPDRS III	43.93	12.76	40.29	12.79	-8.29	3.10	**0.013**	1.27	0.13	2.34
PDQ-39	19.02	12.72	18.27	11.83	-3.93	0.49	0.322	0.20	-0.62	1.00
sFES	11.00	3.02	10.63	3.25	-3.36	0.50	0.317	0.18	-0.53	0.87
sABC	60.83	18.41	58.75	19.37	-3.42	0.78	0.232	0.27	-0.44	0.97
TuG (s)	9.41	2.30	8.36	1.93	-11.17	2.60	**0.018**	**0.92**	0.06	1.73
8.5m walking (s)	7.49	1.00	6.84	0.94	-8.76	5.55	**<0.001**	**1.96**	0.72	3.16
Moderate Intensity Activity (hrs/wk)	2.28	1.53	3.82	3.98	67.58	-1.19	0.137	**-0.42**	-1.13	0.32
Sitting time (hrs/wk)	56.44	25.95	53.81	27.56	-4.65	0.40	0.352	0.14	-0.56	0.83
Hip abductor strength (lbs)	21.66	12.41	19.63	10.81	-9.37	1.17	0.143	**0.44**	-0.35	1.21
Hip adductor strength (lbs)	22.36	12.03	25.84	10.23	15.59	-2.32	**0.030**	**-0.88**	-1.74	0.03
ALM (kg)	18.06	1.36	18.60	2.58	2.99	-0.82	0.221	-0.29	-0.99	0.43
ALMI (kg/m^2)	7.77	2.55	7.87	1.33	1.32	-1.94	**0.047**	**-0.68**	-1.44	0.11
leg lean mass (kg)	10.58	1.71	10.34	1.77	-2.27	4.22	**0.002**	**1.49**	0.44	2.50
trunk lean mass (kg)	27.41	5.41	27.61	5.43	0.73	-0.65	0.267	-0.23	-0.93	0.48
T-score of total lumbar BMD	1.09	0.21	1.10	0.19	0.79	-0.70	0.252	-0.25	-0.95	0.46
T-score of hip BMD	0.76	0.11	0.76	0.13	-0.07	0.03	0.488	0.01	-0.68	0.70
	HiAMD (n=6)									
	Visit 1		**Visit 2**		**% diff**	**t**	**P-value <0.05**	**ES 0.35-5.00 or more Cohen's**	**95% CI**	
	Mean	**SD**	**Mean**	**SD**					**Lower**	**Upper**
MDS-UPDRS II	14.33	9.40	13.20	9.28	-7.91	1.63	0.089	**0.73**	-0.31	1.70
MDS-UPDRS III	42.42	11.86	35.25	9.47	-16.90	2.13	**0.043**	**0.87**	-0.11	1.80
PDQ-39	26.39	21.46	18.80	9.01	-28.75	1.30	0.125	**0.53**	-0.35	1.37
PDQ-ADL	22.22	18.00	15.97	12.20	-28.12	1.22	0.139	**0.50**	-0.38	1.33
sFES	13.60	6.99	11.83	2.64	-13.01	0.76	0.244	0.34	-0.58	1.23
sABC	36.39	22.10	37.50	28.46	3.05	-0.14	0.448	-0.06	-0.85	0.75

Table 3. *(Cont. from previous page).*

	HiAMD (n=6)									
	Visit 1		Visit 2		% diff	t	P-value <0.05	ES 0.35-5.00 or more Cohen's	95% CI	
	Mean	SD	Mean	SD					Lower	Upper
TuG (s)	10.85	3.05	9.93	4.03	-8.45	1.33	0.121	**0.54**	-0.35	1.38
8.5m walking (s)	9.86	3.21	8.39	2.55	-14.90	2.23	**0.038**	**0.91**	-0.09	1.85
Moderate Intensity Activity (hrs/wk)	6.98	7.90	4.44	3.83	-36.46	0.74	0.247	0.30	-0.53	1.11
Sitting time (hrs/wk)	50.17	24.91	50.75	25.02	1.16	-0.08	0.469	-0.03	-0.83	0.77
Hip abductor strength (lbs)	22.12	4.60	24.18	3.98	9.34	-0.81	0.227	-0.33	-1.14	0.51
Hip adductor strength (lbs)	26.12	4.09	26.35	4.58	0.89	-0.15	0.442	-0.06	-0.86	0.74
ALM (kg)	19.65	1.12	19.30	3.28	-1.78	1.85	0.062	**0.75**	-0.19	1.65
ALMI (kg/m^2)	8.46	3.42	8.13	0.86	-3.90	1.30	0.125	**0.53**	-0.35	1.37
leg lean mass (kg)	11.97	3.30	11.29	1.94	-5.68	1.00	0.182	**0.41**	-0.45	1.23
trunk lean mass (kg)	30.72	8.14	30.36	8.05	-1.17	0.74	0.246	0.30	-0.53	1.11
T-score of total lumbar BMD	0.98	0.13	0.96	0.15	-1.28	1.28	0.145	**0.64**	-0.49	1.70
T-score of hip BMD	0.71	0.12	0.68	0.13	-3.79	2.77	**0.020**	**1.13**	0.05	2.15

between the control and the intervention group, it revealed that MDS-UPDRS II, PDQ-39, sFES, sABC, TUG, 8.5m walking test, activity time, sitting time, hip abductor and adductor strength, ALMI, leg lean mass, and T-score of total lumbar BMD all reached the MCID. The difference in hip adductor strength also reached significance. The MDS-UPDRS III did not reach significance or the MCID in this analysis (Table 5).

Discussion

The aim of this study was to investigate the feasibility and effects of a post-PT in-home intervention, replacing sedentary behavior with low-intensity physical activity in PwPD with PIGD. We explored if the combination of standard care (focusing on increasing physical activity by means of a weekly physical exercise group), with the barrier-free in-home intervention facilitating a decrease in sedentary behavior, would be more effective in maintaining the improvements in outcome measures (gait velocity and MDS-UPDRS III) that were made in PT than the current standard care alone. We also explored values of sarcopenia and frailty as well as balance, FoF and QoL.

The results showed that using the HiAMD is safe and feasible for PwPD with PIGD. Compliance with the recommended use was met and even exceeded. The participants were able to perform any activity that they normally would do sitting behind their desk now standing, sidestepping and weight shifting. They reported watching movies, using the computer, completing puzzles, writing, cutting vegetables and folding laundry. There were no serious adverse events or falls reported during the study. During exit interviews the participants were very positive about the HiAMD. Three participants opted to keep the desk for a year after the study was completed. While there was a 33% attrition in this feasibility study, none of the participants discontinued the study because of the HiAMD use. One person was lost to follow up. The others encountered medical or personal crises that prohibited further participation. During the recruitment

Table 4. Within Group Visit 2 vs Visit 3.

	No HiAMD (n=8)										HiAMD (n=6)									
	Visit 2		Visit 3		% diff	t	P-value <0.05	ES 0.35-5.00 or more Cohen's	95% CI		Visit 2		Visit 3		% diff	t	P-value <0.05	ES 0.35-5.00 or more Cohen's	95% CI	
	Mean	SD	Mean	SD					Lower	Upper	Mean	SD	Mean	SD					Lower	Upper
MDS-UPDRS II	10.88	8.98	11.63	6.78	6.90	-0.44	0.335	-0.16	-0.85	0.55	13.20	9.28	7.17	5.38	-45.71	1.39	0.119	**0.62**	-0.38	1.56
MDS-UPDRS III	40.29	12.79	43.13	12.78	7.05	-2.40	**0.026**	**-0.91**	-1.78	0.01	35.25	9.47	38.33	12.73	8.75	-0.95	0.193	**-0.39**	-1.20	0.46
PDQ-39	18.27	11.83	19.55	10.70	7.01	-0.58	0.290	-0.21	-0.90	0.50	18.80	9.01	6.57	7.43	-65.06	1.41	0.127	**0.70**	-0.45	1.78
sFES	10.63	3.25	11.25	3.37	5.83	-0.48	0.324	-0.17	-0.86	0.54	11.83	2.64	11.17	2.71	-5.58	0.65	0.271	0.27	-0.56	1.07
sABC	58.75	19.37	55.00	25.20	-6.38	0.97	0.182	0.34	-0.38	1.05	37.50	28.46	45.83	24.05	22.22	-1.13	0.156	**-0.46**	-1.29	0.41
TuG (s)	8.36	1.93	9.24	2.61	10.57	-2.50	**0.021**	**-0.88**	-1.69	-0.03	9.93	4.03	9.73	2.62	-2.01	0.24	0.409	0.10	-0.71	0.90
8.5m walking (s)	6.84	0.94	7.23	1.60	5.72	-0.98	0.181	**-0.35**	-1.05	0.38	8.39	2.55	8.48	2.09	1.05	-0.34	0.373	-0.14	-0.94	0.67
Moderate Intensity Activity (hrs/wk)	3.82	3.98	2.84	2.19	-25.61	1.10	0.153	**0.39**	-0.34	1.10	4.44	3.83	9.96	14.88	124.41	-0.83	0.221	-0.34	-1.15	0.50
Sitting time (hrs/wk)	53.81	27.56	45.06	22.72	-16.26	1.71	0.066	**0.60**	-0.17	1.35	50.75	25.02	28.00	19.30	-44.83	1.67	0.078	**0.68**	-0.24	1.55
Hip abductor strength (lbs)	19.63	10.81	22.50	11.91	14.63	-2.23	**0.034**	**-0.84**	-1.69	0.06	24.18	3.98	32.92	11.69	36.11	-1.89	**0.059**	**-0.77**	-1.67	0.18
Hip adductor strength (lbs)	25.84	10.23	23.64	12.26	-8.51	0.58	0.292	0.22	-0.54	0.96	26.35	4.58	33.73	7.17	28.02	-2.16	**0.042**	**-0.88**	-1.81	0.11
ALM (kg)	18.60	2.58	18.65	2.37	0.27	-0.34	0.372	-0.12	-0.81	0.58	19.30	3.28	19.47	3.25	0.86	-0.58	0.293	-0.24	-1.04	0.59
ALMI (kg/m^2)	7.87	1.33	7.84	1.14	-0.37	0.27	0.396	0.10	-0.60	0.79	8.13	0.86	8.30	0.98	2.03	-1.06	0.169	**-0.43**	-1.26	0.43
leg lean mass (kg)	10.34	1.77	10.37	1.62	0.29	-0.28	0.394	-0.10	-0.79	0.60	11.29	1.94	11.74	2.68	3.99	-1.34	0.119	**-0.55**	-1.39	0.341
trunk lean mass (kg)	27.61	5.43	27.68	5.57	0.25	-0.28	0.394	-0.10	-0.79	0.60	30.36	8.05	31.27	8.61	3.00	0.25	0.406	0.11	-0.77	0.99
T-score of total lumbar BMD	1.10	0.19	1.09	0.20	-0.44	0.49	0.319	0.17	-0.53	0.87	0.96	0.15	0.98	0.14	2.00	-1.57	0.107	**-0.78**	-1.89	0.41
T-score of hip BMD	0.76	0.13	0.76	0.12	0.58	-0.56	0.297	-0.20	-0.89	0.51	0.68	0.13	0.69	0.12	1.37	-0.73	0.250	-0.30	-1.10	0.54

Difference (V2 vs V3)	No HiAMD		HiAMD		P-value <0.05	ES 0.35-5.00 or more Cohen's	95% CI	
	Mean	SD	Mean	SD			Lower	Upper
MDS-UPDRS II	-0.75	4.77	4.60	7.40	0.10	**-0.91**	-2.07	0.29
MDS-UPDRS III	-4.29	4.72	-3.08	7.95	0.38	-0.19	-1.28	0.91
PDQ-39	-1.28	6.23	10.26	14.57	0.11	**-1.21**	-2.49	0.12
sFES	-0.63	3.70	0.67	2.50	0.23	**-0.40**	-1.46	0.68
sABC	3.75	10.90	-8.33	18.13	0.09	**0.84**	-0.28	1.93
TuG (s)	-0.88	1.00	0.20	2.03	0.13	**-0.72**	-1.80	0.39
8.5m walking (s)	-0.39	1.13	-0.09	0.63	0.27	**-0.32**	-1.38	0.76
Moderate Intensity Activity (hrs/wk)	0.98	2.51	-5.52	16.24	0.19	**0.61**	-0.49	1.68
Sitting time (hrs/wk)	8.75	14.49	22.75	33.41	0.19	**-0.58**	-1.65	0.52
Hip abductor strength (lbs)	-2.87	3.41	-8.73	11.31	0.13	**0.73**	-0.42	1.85
Hip adductor strength (lbs)	2.20	10.04	-7.38	8.38	**0.04**	**1.03**	-0.16	2.18
ALM (kg)	-0.05	0.42	-0.17	0.70	0.36	0.21	-0.86	1.27
ALMI (kg/m^2)	0.03	0.30	-0.17	0.38	0.16	**0.58**	-0.51	1.65
leg lean mass (kg)	-0.03	0.30	-0.44	0.81	0.14	**0.73**	-0.38	1.81
trunk lean mass (kg)	-0.07	0.73	0.07	0.60	0.36	-0.20	-1.32	0.92
T-score of total lumbar BMD	0.00	0.03	-0.02	0.03	0.11	**0.78**	-0.49	2.01
T-score of hip BMD	0.00	0.02	-0.01	0.03	0.38	0.18	-0.88	1.24

Table 5. Between Group Visit 2 vs Visit 3.

phase there were 19 potential participants that were contacted and did not complete or failed the screening. Reasons for this were not able to commit to the time, living too far away, illegible due to diagnoses other than PD, or no PIGD, too busy or not interested in this study. Barriers to recruitment and retention of studies with the elderly population are extensively studied and recognized[26]. Future studies will include these numbers in their calculations to achieve appropriate statistical power.

The results showed significantly improved gait velocity immediately after PT. After 4 months, these gains were maintained in the intervention group. Additionally, there were improvements in measures of sarcopenia, frailty, strength, balance, FoF and QoL.

Physical Therapy has long been a staple in the management of PD[7,27-30]. A Cochrane review[31] evaluated the effectiveness of PT interventions in PwPD and concluded that a wide range of PT interventions are effective, at least in the short term. However, maintaining these goals once the PT has ceased, has been reported to be less effective[32]. Tomlinson et al.[32,33] confirms the benefit over the short term (1-3 month) after completion of PT for a number of gait and balance outcome measures. While Clarke et al.[34] reported no clinically meaningful improvements in activities of daily living or quality of life (QoL) post-PT over the longer term (i.e., 3, 9 and 15 months), Mak et al.[35] reviewed a number of studies showing long term benefits of sustained Tai Chi, dance, strength or aerobic training and Okada at al.[36]

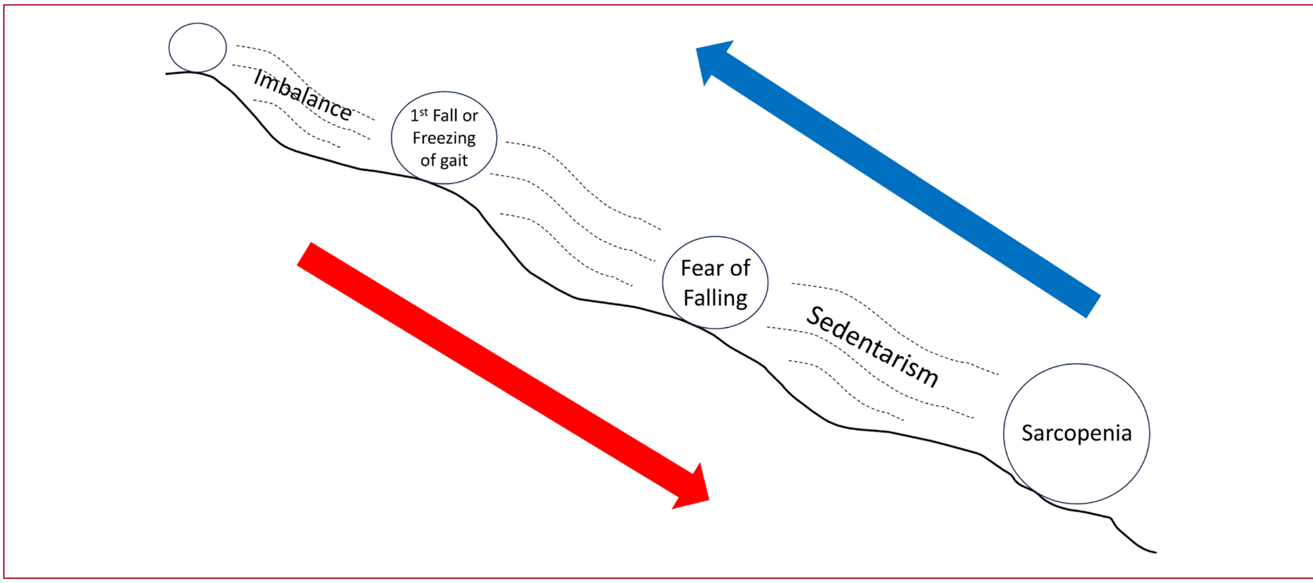

Figure 4. Visual concept of HiAMD use.

conclude in their systematic review and meta-analysis that long term physical therapy is beneficial for motor symptoms and antiparkinsonian medication dose. Similarly, Au et al.[37] concluded that long-term, spread-out sessions of PT were better at maintaining functionality than short bursts of PT. Our cohort showed a significant improvement at V2 (Post-PT) in the TUG, 8.5m walking test, and the MDS-UPDRS III. More importantly, our data showed that after the intervention, (V3) in the control group, there was a trend toward Pre-PT values with TUG and MDS-UPDRS III where initial gains were made. This is consistent with Tomlinson et al[33]. However, the intervention group was able to maintain the values of the TUG and the 8.5m walking test. This is an important finding. Currently the only strategy to maintain PT gains after completion of the therapy sessions is to participate in exercise programs, and if the compliance wanes, the gains are lost over time. This study suggests that decreasing sedentary behavior at home could be a helpful tool in maintaining the gains that made in PT. Our preliminary results suggest that the HiAMD could potentially address this urgent unmet need in the care of PwPD, by means of a novel post-PT in-home intervention, integrated in iADL. Upright standing enhanced with weight shifting may be an ideal form of physical activity. The very nature of standing naturally promotes conditioning of postural reflexes. The added function of weight-shifting and sidestepping may aid complex postural and gait functions, such as step initiation and postural motor skills while at the same time strengthening musculature and providing a reciprocal rather than a continuous loading of the joints[38–41]. Thus, changes in posture and movement while performing iADL behind this desk may be an effective novel approach to replace sedentary behavior with physical activity in PwPD with PIGD problems. It is important to note that the aim of the HiAMD was not to replace participation in any physical exercise, physical therapy or physical activity programs that are evidenced-based and are abundantly used by the Parkinson's community. Rather, the HiAMD helped to decrease sedentary time during the remainder of the day (14-16 hours) when people are not physically active. The 2.2 hours that were spent behind the desk, standing and moving, added about 15.4 hours of (light intensity) physical activity a week that would otherwise be spent sedentary. To our knowledge there are no such options for PwPD at this time despite awareness that sedentary behavior is more prevalent in PwPD than in age controlled peers and needs to be addressed[2,15,42].

The results of other explorative outcome measures regarding sarcopenia and frailty as well as balance, FoF and QoL were promising and important. Sarcopenia is commonly seen in elderly with chronic diseases, including PD[43–45] and is an important determinant of QoL, disability, and mortality[46,47]. Peball et al.[48] found that sarcopenia is more common in the PwPD than in the general community and it is associated with a more severe disease course. Ellingson et al.[15] found a negative correlation in PwPD between sedentary behavior and QoL. In addition, recent studies studied the relationship between sarcopenia and falls in PD[49,50]. There is increasing evidence that inactivity physiology and exercise physiology appear to have independent effects on health outcomes[13,51–53]. This means that the positive effects of regular exercise do not compensate for the negative effects of excessive sedentary behavior. Nonetheless, the concept of addressing sedentary behavior is still widely underused in the clinical setting. Benka Wallen et al[54]. concluded that there is a critical need to develop strategies to decrease sedentary behavior in patients with mild to moderate PD. A large multicenter study aimed at increasing physical activity for PwPD by means of a behavioral change program tried, but failed to achieve this goal[9]. Recently, the concept of Isotemporal Substitution has been used to analyze data of activity levels[17,18,55]. This model considers that to increase one level of activity, another type must be reduced, given that time is a limited resource. Van Nimwegen et al.[2] reported that PwPD are about one third more sedentary than their age controlled peers. Lerma et al.[17] found that replacing 30 minutes a day of sedentary behavior with low-intensity physical activity significantly improved the 400m walk test in older adults. Nagai et al.[55] concluded that replacing 30 min of sedentary behavior with low-intensity physical activity decreases the risk for frailty in older adults. Interestingly they also concluded that increasing low-intensity physical activity seems more feasible than increasing moderate to vigorous physical activity in older adults. While Sánchez- Sánchez et al.[56] concluded that replacing sedentary behavior with low-intensity physical activity was not associated with a reduction in sarcopenia prevalence, Dogra et al.[16] pleads for a more practical approach to start replacing sedentary behavior with low-intensity physical activity in people with chronic diseases as an initial step toward a more active lifestyle. The first and foremost treatment of sarcopenia is resistance exercise. Standing/stepping being a closed kinetic chain activity falls under resistance exercise even when it is considered low intensity physical activity Our intervention group replaced an average of 2.4 hours a day, 5 days a week (a total of 11+ hours) of sedentary behavior with closed kinetic chain low-intensity physical activity: standing and sidestepping, in the home environment, completely integrated in their activities of daily life, therefore circumventing many of the barriers for increasing physical activity that exist for PwPD[20]. As a result, hip abductor and adductor strength, ALMI, leg lean mass all reached the MCID. The difference in hip adductor strength also reached significance. Thus, 11+ hours of replacing sedentary time with standing and stepping (integrated in ADL) appears to give the user a tool to prevent or mitigate the onset of sarcopenia by means of strengthening the large hip musculature most important for maintaining balance in the frontal plane, as well as improving body composition away from sarcopenia. Interestingly, Martinez et al[57] found that a TUG cut off value of greater than 10.85 seconds was able to predict sarcopenia in elderly hospitalized patients. (Sensitivity 67%, specificity 88.7%). While we are dealing with a different population here, the TUG values were maintained in the intervention groups while they regressed in the control group giving support to the hypotheses that decreasing sedentary time and replacing it with standing and stepping, i.e. close kinetic chain, low intensity physical activity can be a new and powerful tool to prevent the onset or mitigate the progress of sarcopenia. The results in the intervention group of this study show some interesting and important trends. Sitting time, activity time, sABC and PDQ-39, all improved within or beyond the MCID range while in the control group all these scores regressed. When we look at the difference in % change between the intervention and the control group we see that the MDS-UPDRS II, TUG, 8m walking test, moderate activity time sitting time, sABC, FES and PDQ-39 all reached or exceeded the MCID. Of special interest is the significant improvement of the hip adductors as well as the nearly significant improvement of the hip abductors in the intervention group. Both hip adductors and abductors are important for hip stabilization. Age is a risk factor for weak adductors and abductors, which in turn is correlated with balance impairment and falls[58]. A cross sectional study[59] revealed that in people with mild PD the hip adductors had 67% weaker isometric force production than their age controlled peers. There is evidence that hip abductor weakness is a potential risk factor for falls to the side due to its association with increased medial–lateral sway[60–64]. There is also evidence that improved hip abductor strength and sidestepping performance are associated with lower fall risk in older adults and PwPD[62,65,66]. Kwakkel et al.[29] suggest that the effects of PT are task- and context-specific and that future programs should train meaningful tasks preferably in patients' home environment. They also plead for more permanent treatment of patients with PD mainly "chronic treatment for this chronic disease". Standing and sidestepping during iADL activities in the home environment might be an appropriate intervention to meet this yet unmet need.

Finally, the result showed that the intervention group increased their physical activity level beyond the use of the desk, indicating a carry-over effect into ADL. Thus, using this HiAMD seemed to facilitate more physical activity in general. This is a very important finding because many studies aim at, or conclude that more physical activity is needed for PwPD[2,7,67]. The HiAMD intervention seems to counteract the downward spiral caused by PIGD: the first fall or freeze might introduce more sedentary behavior eventually resulting in sarcopenia and frailty and increased PD symptoms. Figure 4 visualizes this concept: Where PIGD symptoms start a downward slope from FoF towards increasing sedentary behavior ultimately resulting in sarcopenia, the use of the HiADM seems to mitigate this by replacing sedentary behavior with physical activity (beyond the use of the HiAMD), resulting in improved measures of sarcopenia and frailty, balance, decreasing FoF and ultimately increasing QoL.

Limitations

Our Cohort was small and had a 33% attrition rate. This study was 6 months long and with any long duration study in the elderly population, the attrition is expected[26,68]. Importantly, the attrition was not caused by the HiAMD intervention itself. The reasons for attrition in our study were related to personal events. Additionally, despite the randomization the intervention group had a higher Hoehn and Yahr stage but a shorter disease duration, a lower sABC score and a higher hip abductor strength. This discrepancy appeared after the 33% attrition. However, the difference in change between the groups between visit 2 and visit 3 meets the MCID range and is therefore clinically relevant. Also note the difference in direction of change: the intervention group improved while the control group maintained or regressed. There is also an under-representation of females. The prevalence of PD is known to be higher in males than in females[69]. However, in a larger study, females should be represented more to allow better generalization of our findings to the overall PD population. Another limitation of the study is that we used an 8.5 meter walking test, which will need further validation for the use in PwPD. Finally, while there were MCID range changes in some of the DXA measures, they should be interpreted with caution given the absolute small differences and the short-term duration of the study.

Conclusion

Replacing sedentary behavior with physical activity in the home environment is an underused but promising approach to maintain initial gains made in PT and to mitigate the effects of PD and subsequent sedentary behavior. This is the first study to the best of our knowledge that tested an in-home, post-PT intervention integrated with desktop iADL functions) aimed at replacing sedentary behavior with physical activity in PD. This feasibility study showed that it is safe and feasible to use the HiAMD in the home environment for PwPD with PIGD. The intervention group maintained gains made in PT while in the control group there was a trend toward pre-PT status. Moreover, consistent use of the HiAMD of 2.4 hours a day for 5 days a week, over a period of 4 months showed that physical activity levels (hrs/wk) increased beyond the use of the HiAMD itself indicating a carryover effect into ADL. There was a decrease in FoF and an increase in balance and QoL. While the cohort was small and there were baseline discrepancies, outcome measures passed the MCID range.

Because there is currently no cure available for PD, the overall aim of PT is to optimize independence, safety, and well-being to ultimately enhance QoL. If the findings of this feasibility study are confirmed in a larger multicenter study, the HiAMD would fill a critical need by providing a low barrier option of replacing sedentary behavior with functional, integrated physical activity, to be used in conjunction with continuing participation in physical exercise. This post-PT, in-home intervention offers a novel tool to maintain gains made in individual PT. The HiAMD appears to interrupt the downward slope from sedentary behavior towards sarcopenia by decreasing sedentary behavior as well as FoF, increasing hip abductor and adductor strength resulting in increased physical activity and ultimately increased QoL for PwPD.

Ethical Approval

The protocol was reviewed and approved by the Institutional Review Board at the University of Michigan under ID HUM00118467

Consent to participate

Written informed consent was obtained from all patients prior to the start of the study.

Authors' Contributions

Miriam van Emde Boas: Research Project Conception, Research Project Organization, Research Project Execution, Manuscript Preparation Writing the First Draft, Manuscript Preparation Review and Critique. Chatkaew Pongmala: Statistical Analysis Design, Statistical Analysis Execution, Statistical Analysis Review and Critique, Manuscript Preparation Writing the First Draft, Manuscript Preparation Review and Critique. Abbigail M Biddix: Statistical Analysis Execution, Manuscript Preparation Review and Critique. Alexis Griggs: Manuscript Preparation Review and Critique. Austin T Luker: Manuscript Preparation Review and Critique. Uros Marucic: Manuscript Preparation Review and Critique. Giulia Carli: Statistical Analysis Execution, Statistical Analysis Review and Critique, Manuscript Preparation Review and Critique. Nicolaas I Bohnen: Research Project Conception, Research Project Organization, Research Project Execution, Statistical Analysis Design, Statistical Analysis Execution, Statistical Analysis Review and Critique, Manuscript Preparation Writing the First Draft, Manuscript Preparation Review and Critique. All authors read and approved the final version of the manuscript.

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