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Assistive devices alter gait patterns in Parkinson disease: Advantages of the four-wheeled walker

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ABSTRACT

Gait abnormalities are a hallmark of Parkinson's disease (PD) and contribute to fall risk. Therapy and exercise are often encouraged to increase mobility and decrease falls. As disease symptoms progress, assistive devices are often prescribed. There are no guidelines for choosing appropriate ambulatory devices. This unique study systematically examined the impact of a broad range of assistive devices on gait measures during walking in both a straight path and around obstacles in individuals with PD. Quantitative gait measures, including velocity, stride length, percent swing and double support time, and coefficients of variation were assessed in 27 individuals with PD with or without one of six different devices including canes, standard and wheeled walkers (two, four or U-Step). Data were collected using the GAITRite and on a figure-of-eight course. All devices, with the exception of four-wheeled and U-Step walkers significantly decreased gait velocity. The four-wheeled walker resulted in less variability in gait measures and had less impact on spontaneous unassisted gait patterns. The U-Step walker exhibited the highest variability across all parameters followed by the two-wheeled and standard walkers. Higher variability has been correlated with increased falls. Though subjects performed better on a figure-of-eight course using either the four-wheeled or the U-Step walker, the four-wheeled walker resulted in the most consistent improvement in overall gait variables. Laser light use on a U-Step walker did not improve gait measures or safety in figure-of-eight compared to other devices. Of the devices tested, the four-wheeled-walker offered the most consistent advantages for improving mobility and safety.

1. Introduction

Gait and balance problems in individuals with PD cause frequent falls [1]. Falls typically occur while a person is turning, initiating gait, and sitting down [1]. Fractures from falls are higher in patients with PD compared with age-matched controls [2,3]. Thus, fall prevention is important for PD clinical management.

As PD symptoms progress, clinicians may prescribe assistive devices (ADs). Typically canes are prescribed for mild and walkers for more severe gait problems. In individuals with PD, use of a cane, standard or four-wheeled walker has been found to significantly reduce walking speed [4,5] and standard walker use induced more freezing of gait (FOG) when compared to unassisted walking [4]. Four-wheeled walker use significantly reduced stride length, while other gait parameters (i.e. cadence, double support percent, heel-to-heel base of support, stride and stance times) were unaffected by usage of assistive device compared to walking without a device [5]. To overcome FOG and/or improve step length, ADs with lasers that project a light to step over are prescribed. One study [4] found no reduction in FOG with laser attached to a four-wheeled walker while another reported a modest decrease in freezing with laser attached devices. People with PD may be more likely to abandon use of an AD if it causes reduced speed [6,7]. Knowledge of the potential effects of ADs on gait measures in PD may improve prescription practices and patient compliance.

Previous studies that investigated gait changes with assistive device use in people with PD utilized only a limited number of devices and did not investigate gait variability or walking around obstacles which could increase fall risk [4,5]. Therefore the purpose of this study was to compare spatiotemporal gait measures in individuals with PD while using a wide variety of commonly prescribed ADs during both walking in a straight path and maneuvering around obstacles. Based on previous findings in PD [4], and other patient populations [8–12], we hypothesized that spatiotemporal gait measures and variability would be: (1)

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different when participants ambulated with an AD compared to without; (2) improved when participants ambulated with swivel-wheeled walkers (i.e. four-wheeled or U-Step walkers) compared to walkers without; and (3) improved with laser light use. We also hypothesized that gait speed would be improved and there would be fewer balance losses and FOG episodes during turns when participants used swivel-wheeled walkers compared to devices without swivel wheels. Identification of effective ADs will enable clinicians to make more appropriate AD prescriptions for individuals with PD.

2. Methods

Participants were volunteers recruited via written and verbal communication from individuals who attended our clinic and/or a community exercise class and were consented in to the study. A target recruitment number of 30 was set a priori; all volunteers met inclusion criteria but only 27 individuals entered the study. Inclusion criteria were a diagnosis of PD confirmed by a neurologist; age >50; ability to walk a minimum of 10 m without an AD or assistance; absence of any additional central nervous system disorders; and absence of orthopedic and peripheral neurological disorders affecting the lower extremities. Since individuals with PD have abnormal gait patterns compared to healthy individuals, participants were used as their own controls with the no AD condition as the comparison or baseline condition. The study was approved by the University Institutional Review Board.

Spatiotemporal gait measures were collected using the GAITRite System® (CIR systems). The GAITRite measures are valid and reliable in people with PD [13]. An aluminum straight cane (cane) (Harvey Surgical Supply Corporation), a standard walker (StW) (Graham-Field Health Products), a two-wheeled walker (2WW) with fixed wheels (Medline Industries), a four-wheeled walker (4WW) with front swivel casters (Invacare Corporation) and a U-Step walker (UstW) with six swivel wheels and a laser (In-Step Mobility Products) were utilized. All ADs were adjusted to fit each participant.

The Unified Parkinson Disease Rating Scale (UPDRS) motor scale [14] was administered by an investigator (DK) and demographic data including age, sex, and number of years since symptom onset was obtained. Participants reported any falls in the past 6 months. Data were normalized to each person's height.

Prior to testing, a therapist trained each participant on an AD. Training time was individualized until the participant demonstrated correct and safe device use as determined by observation of a smooth, continuous forward progression with gaze directed forward and without loss of balance. During walking trials with the UstW, the laser was turned on at all times and participants were told to step over the light beam but not to use the light beam for every step in order to maintain a forward gaze. Training time was generally equivalent to time typically spent in our clinic to teach device use. Participants then walked at a normal, comfortable pace across the GAITRite carpet for four trials under each of the conditions. The first trial was a practice trial. The GAITRite software averaged the data from the remaining three trials for each condition. Participants began walking 2 m before and stopped 2 m beyond the carpet edges to allow for acceleration and deceleration. Participants wore a gait belt and were guarded at all times during testing.

To test maneuverability around obstacles, participants were timed while they walked as fast as they could in a figure-of-eight pattern around two chairs set 4 feet apart under all six conditions. Each participant performed the course twice; the time to complete the second trial was recorded. Investigators also recorded the number of freezing episodes (completely stopped then resumed walking), number of stumbles (loss of balance with unassisted recovery), and falls (loss of balance with assistance for recovery). Device use order was randomized and participants could rest whenever necessary.

Coefficient of variation (CV) values were calculated to assess the variability of gait measures across devices. For CV, the average time series of steps across three walkway trials was utilized to calculate the mean and standard deviation. Data for each of the gait measures and CVs were normally distributed and were analyzed using one-way repeated-measures ANOVA to detect differences between the different walking conditions. Tukey post hoc testing was used to adjust for multiple comparisons and to control the type I error rate at .05. Significance was set a priori at <.05. All statistical analysis was performed using SAS Version 9.2.

3. Results

Participants' (27) average age was 69.7 ± 1.3 years old (range 55–83 years), and they were 8.3 ± 7.1 years post diagnosis (range <1–30 years) with UPDRS motor scores of 24.2 ± 2 (range 9–44). There were more men (22) than women (five). Fourteen of the 27 participants (52%) reported falls in the last 6 months. All participants reported being at optimal drug effect (i.e. "on" time) during the testing session. No participants regularly utilized an AD, although a few reported having used an AD in the past. All participants exhibited gait and balance deficits on the UPDRS and GAITRite.

3.1. Gait measures across ADs

In comparison to the no AD condition (baseline), walking velocity with the 4WW was statistically equivalent while all other ADs produced significantly ($p < .05$) decreased mean velocity (Table 1). Analysis of differences between gait parameters across ADs showed that walking with the 4WW produced a gait pattern that was most similar to the no AD condition with respect to higher velocity (1.01 ± .04 m/s), longer stride length (118.6 ± 3.9 cm), and more of the gait cycle spent in swing (37.2 ± .40%) and less in double support (26.6 ± .73%) (Table 1). The cane produced a gait pattern much like the no AD and 4WW conditions but with significantly slower velocity (.94 ± .05 m/s) as compared to no AD (1.08 ± .04 m/s). Standard walker use produced the lowest velocity (.63 ± .05 m/s) and shortest stride length (96.6 ± 5.5 cm) of all devices ($p < .05$). The 2WW also produced a slow (.80 ± 5.3 m/s) gait compared to all other conditions ($p < .05$) with shorter stride lengths (93.1 ± 5.5 cm) while the UstW produced a gait with prolonged time in double support (50.5 ± 2.9%) and less time in the swing phase of gait (27.0 ± 1.7%) as compared to all other conditions ($p < .05$). The narrowest base of support was achieved with the UstW (7.7 ± 4.2 cm; $p < .05$).

Table 1
Gait measures across all walking conditions: mean (standard error).

	No AD	Cane	Standard walker	Two wheel walker	Four wheel walker	U Step walker
Velocity (m/s)	1.08	$.94^{*,\#,+}$	$.63^{**}$	$.80^{**}$	$1.01^{\#,+}$	$.96^{*,\#,+}$
	(.04)	(.05)	(.05)	(.05)	(.04)	(.05)
Stride length (cm)	119.9	$117.1^{\#,+}$	$96.6^{*,\S}$	$93.1^{*,\S}$	$118.6^{\#,+}$	$121.2^{\#,+}$
	(4.5)	(4.3)	(5.5)	(5.8)	(3.9)	(4.9)
Swing	37.5	$36.6^{\dagger}$	$34.5^{\dagger}$	$34.0^{\dagger}$	$37.2^{\dagger}$	27.0^{**}
%gait cycle	(.43)	(.51)	(1.1)	(.97)	(.40)	(1.7)
Double support	26.3	$29.1^{\dagger}$	$34.1^{*,\dagger}$	$33.6^{\dagger}$	$26.6^{\dagger}$	50.5^{**}
%gait cycle	(.71)	(1.6)	(2.0)	(2.6)	(.73)	(2.9)
Base of support (cm)	9.8	$9.6^{\dagger}$	9.3	$9.8^{\dagger}$	8.9	$7.7^{*,♌}$
	(3.2)	(3.0)	(6.4)	(2.2)	(2.3)	(4.2)

Abbreviation: CV, coefficient of variation.
* Significantly different than no AD at $p < .05$.
** Significantly different than all other conditions at $p < .05$.
# Significantly different than StW at $p < .05$.
+ Significantly different than 2WW at $p < .05$.
† Significantly different than UstW at $p < .05$.
♌ significantly different than cane, 2WW at $p < .05$.
§ Significantly different than cane, 4WW, Ust at $p < .05$.

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Table 2
Coefficient of variation across all walking conditions: mean (standard error).

	No AD	Cane	Standard walker	Two wheel walker	Four wheel walker	U Step walker
Step time CV	4.4	$10.5^{\dagger}$	$19.5^{*,\infty,\dagger}$	$12.1^{\dagger}$	$4.7^{\#,\dagger}$	35.9^{**}
	(.4)	(2.9)	(6.9)	(3.1)	(.4)	(3.1)
Stride length CV	5.2	$7.2^{\#}$	$15.3^{*,\S}$	11.6	$5.0^{\#}$	$5.1^{\#}$
	(1.1)	(2.1)	(3.6)	(2.5)	(.55)	(.57)
Swing time CV	6.6	$8.9^{\dagger}$	23.8	$12.7^{\dagger}$	$5.8^{\dagger}$	$40.2^{*,\ddagger}$
	(1.6)	(1.5)	(9.0)	(2.3)	(.66)	(7.1)
Double support CV	10.3	18	23.8	20.2	$10.4^{\dagger}$	$30.0^{*,\infty}$
	(.9)	(4.8)	(4.5)	(5.7)	(.6)	(2.8)

Abbreviation: CV, coefficient of variation.
* Significantly different than no AD at $p < .05$.
** Significantly different than all other conditions at $p < .05$.
\# Significantly different than StW at $p < .05$.
∞ Significantly different than 4WW at $p < .05$.
† Significantly different than UstW at $p < .05$.
‡ Significantly different from cane, 2WW, 4WW at $p < .05$.
§ Significantly different than cane, 4WW, Ust at $p < .05$.

3.2. Gait variability

Walking with the 4WW produced low CVs as compared to other devices on step to step measures (Table 2). Higher CV's were seen with the UstW and StW as compared to the no AD condition ($p < .05$).

3.3. Gait through a figure-of-eight

Overall the 4WW and UstW improved safety and efficiency when maneuvering through a figure-of-eight course. Time to walk through the figure-of-eight was slower ($p < .05$) with the standard cane (19.4 ± 4.78 s), StW (23.4 ± 2.24 s) and 2WW (25.2 ± 4.16 s) as compared to no AD (16.7 ± 4.96 s), 4WW (16.3 ± 1.16 s) and the UStW (16.0 ± 1.0 s) (Table 3). Freezing episodes occurred with all devices with the highest frequency observed with the 2WW, followed by the cane (Table 3). In contrast, the 4WW and UstW induced the fewest incidences of freezing. Two individuals who exhibited freezing in all conditions showed the fewest episodes while walking with the 4WW and UstW. There were seven falls recorded, three of which occurred in the no AD condition and four with the standard cane. Stumbles were recorded with the StW and 2WW.

4. Discussion

Our results demonstrate the significant impact that ADs have on gait patterns of individuals with PD and extend previous findings by including a broad range of devices and examining gait during both walking straight and maneuvering around obstacles. Of the devices studied, the 4WW demonstrated the most improved safety and speed when making turns while producing a gait pattern with the least variability and impact on individuals' abilities to walk at their usual speed. In contrast, the standard walker produced the slowest and most variable gait pattern of all of the devices when walking straight. During turns, individuals with PD walked the slowest and had the greatest numbers of freezing episodes with a 2WW. Use of a laser light walker did not improve gait patterns compared to standard wheeled walkers.

The 4WW produced a gait that was statistically equivalent to the spontaneous gait without an AD and with more stability when maneuvering. This finding concurs with our study examining AD use in individuals with Huntington's disease [8] and with a study by Alkjaer et al. [15] Gait improvements with the 4WW over no AD were faster time, no falls and less FOG in the figure-of-eight course. The 4WW's greater stability and ease of use may underlie these improvements. Device users must manipulate a cane, StW and 2WW in time with their gait pattern whereas they can push a 4WW or UStW without lifting it. Ease of use is a concern when prescribing ADs for individuals with PD who have difficulties with learning movement sequences and dual tasks during gait [16,17]. The 4WW is easy to use while providing adequate support to prevent falls. Device compliance may improve if individuals are prescribed an AD that does not worsen bradykinesia intrinsic to this disorder.

Gait with the UStW was equivalent to the 4WW across several parameters but participants spent more time in stance phases of gait and the UstW produced the highest variability in three out of four gait measures. Increased stance time is typically an indicator of impaired balance or fear of falling [18]. One possible explanation is that the UstW's added weight makes manipulating it more difficult than the 4WW. The UstW has a reverse brake requiring the user to squeeze the brake in order to propel the walker which may increase complexity of use

Table 3
Comparison across devices of time to complete and safety in the figure-of-eight.

Device	No AD	Cane	Standard walker	Two-wheeled walker	Four-wheeled walker	U-Step walker
Time to complete (s) (SE)	16.68	19.37^{*}	$23.45^{\infty,\dagger}$	25.18^{*}	$16.32^{\#}$	$16.02^{\#}$
	(4.96)	(4.78)	(2.24)	(4.16)	(1.16)	(1.0)
# of freezes	7	11	9	17	3	2
# of participants with freezing	3	4	5	6	2	1
# of stumbles	6	7	3	1	0	0
# of falls	3	4	0	0	0	0

Abbreviation: AD, assistive device.
* Significantly different than no AD at $p < .05$.
\# Significantly different than StW at $p < .05$.
∞ Significantly different than 4WW at $p < .05$.
† Significantly different than UstW at $p < .05$.

compared to the 4WW. Stepping over the laser light is a novel task and requires looking down at the ground periodically to see the laser. It may be that this novel task induced increased time in double stance and increased variability. Future studies should be conducted after longer-term use of the UstW to rule out novelty as a cause of these problems. Examination of kinematic data which was collected but not yet analyzed may provide further insight.

The 2WW and StW produced decreased velocities and stride lengths compared to other ADs on a straight path. Similar findings were reported by Mahoney et al. [9,19]. One explanation is that the wheels on the 2WW are smaller and do not roll as smoothly as those on the 4WW. Standard walkers have high attentional requirements [20] and so are of concern since individuals with PD may perform poorly in dual task situations that require divided attention [16,21,22].

A small study on 10 individuals with PD found that stride length was reduced with cane and wheeled walker use compared to unassisted walking [5]. The type of wheeled walker was unspecified making it difficult to compare their results with ours. The findings of this study are in agreement with theirs regarding cane use. If we assume that they utilized a 4WW their findings differ from ours. One explanation is that participants in the Bryant et al. [5] study did not practice walking with the devices and were tested as novice users. Our participants were trained until they used each device comfortably and appropriately, thus producing gait patterns more closely resembling those during everyday use of the device.

Gait measure CVs were lower with the 4WW than with other devices. This may be clinically important, as higher variability correlates with increased falls [23,24]. The UStW exhibited the highest variability across three out of four CVs followed by the 2WW and StW. Gait with a cane had lower CVs than the standard, 2WW and UstWs but had higher variability than the 4WW and no AD. These findings indicate that participants adopted a safer and more invariant gait when utilizing the 4WW. Based on previous studies [23,24], low variability when utilizing the 4WW indicates a lower fall risk with this device.

An effective intervention for FOG in PD is the use of visual cues [6,25]. Thus, clinicians incorporate visual cueing with a laser light that is attached to the UstW. We found that neither velocity nor stride length improved with use of the UstW. This finding concurs with findings by Cubo et al. and Kompoliti et al. [4,26] but conflicts with those of Donovan et al. [6] However, our study was not designed to examine the influence of ADs on individuals with daily reports of FOG, as in the Donovan study, and therefore our findings are limited in scope to the impact of these AD's on FOG during our figure-of-eight task and not on FOG in general. Individuals who report daily functional impairment due to freezing, as in the Donovan et al. [6] study, may respond differently to ADs than our participants.

Maneuverability is an important factor to consider when prescribing an AD as many individuals with PD fall when turning or avoiding obstacles [1]. To prevent falls, an AD must provide support while turning corners and maneuvering in tight spaces. The figure-of-eight course appeared to be a sensitive measure of the ability to make turns and safely maneuver around objects. As anticipated, participants walked the fastest and had fewer stumbles when using the 4WW and UStW which allow turning without additional device manipulation. In contrast, the 2WW must be picked up during turns, thus providing no support during turns and this may account for its poor performance on the figure-of-eight course. Individuals with PD tend to make en bloc turns. To improve stability during turns, clinicians encourage taking larger steps and enlarging the radius of the turn. The added support of an AD that allows for smooth turns with larger steps and radius may be beneficial in PD. Safety was best with 4WW and UstW use and worst with no AD, cane, StW and 2WW use based on numbers of falls and stumbles. These findings indicate that subjects were able to make turns and changes in direction in a more timely and safe manner with swivel-wheeled walkers.

Fall prevention is a critical component of care for individuals with PD. Given the frequency with which ADs are prescribed, it is critical that clinicians have evidence on which to base their recommendation of AD. This study provides evidence that gait with the 4WW produced a pattern most similar to the individual's spontaneous pattern with no AD and did not decrease velocity or increase variability, as did the other devices. In addition, the 4WW produced a safer and smoother gait when making turns. Thus, the 4WW appears to be a good choice of AD for promoting safe ambulation in individuals with PD.

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Conflict of interest statement

There are no conflicts of interest.

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