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ORIGINAL

Evaluation of Gait Assistive Devices in Patients with Parkinson's Disease

Mi-Young Kim[1], Bee-Oh Lim[2]

[1]Department of Exercise Rehabilitation Welfare, College of Human Ecology, Sungshin Women's University, Seoul, South Korea
[2]Department of Physical Education, College of Education, Chungang University, Seoul, South Korea

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Corresponding Author
Bee-Oh Lim
Department of Physical Education, College of Education, Chungang University, 308-ho, 303-kwan, 84 Heukseok-ro, Dongjak-gu, Seoul, 06974, South Korea
Tel : +82-2-820-5121
Fax : +82-2-812-2729
Email : bolim@cau.ac.kr

Objective: There are no guidelines for choosing appropriate gait assistive devices. The aim of this study was to evaluate gait assistive devices in patients with Parkinson's disease.

Method: We evaluated 15 individuals with Parkinson's disease who did or did not use one of two different devices including canes and two-wheeled walkers. Data were collected using the GAITRite system.

Results: Participants in the group using canes and two-wheeled walkers had significantly increased double support time and decreased gait velocity, normalized gait velocity, and stride length compared with those who did not. Participants who used a two-wheeled walker had significantly decreased gait velocity, normalized gait velocity, and stride length compared with those who used a cane. Furthermore, participants who used a two-wheeled walker had significantly decreased coefficients of variation for step time, stride length, and swing time compared with those who used a cane.

Conclusion: Our results indicated that the two-wheeled walker offered the most consistent advantages for decreasing the risk of falling.

Keywords: Gait, Assistive devices, Parkinson's disease, Hoehn and Yahr scale

INTRODUCTION

Patients with Parkinson's disease (PD) are confronted with challenges in gait, one of the most basic motions needed for daily living activities, which leaves them susceptible to fall injuries (Bloem, Beckley, Remler, Roos & Van Dijk, 1995). Falling occurs as a result of the lack of muscle strength and flexibility, postural instability, imbalance, and impaired cognitive reaction (Tinetti, Baker & Horwitz, 1994; Canning, Sherrington, Lord et al., 2009), and the prevalence of falls has reached 68.3% in PD patients whereas that among the general elderly population remains at approximately 30% (Brod, Mendelsohn & Roberts, 1998; Tinetti et al., 1994; Canning et al., 2009). Furthermore, approximately 46% of all PD patients experience fall injuries each year, which is approximately twice as much as the proportion of falls in the general elderly population (Bloem, Hausdorff, Visser & Giladi, 2004). A 12-month prospective study on 113 PD patients reported that approximately 27% of PD patients experience a fall at least once a month, and 15% experience a fall at least once a week (Latt, 2006). Approximately 33% of all falls result in fractures, which induce pain and reduce motor abilities in the patients while causing severe stress in caregivers. Frequent falls are highly dangerous, as they severely undermine physical activities and even threaten the lives of the patients (Bishop, Brunt, Pathare & Marjama-Lyons, 2005). Therefore, prevention of falls is critical in the clinical management of PD patients (Kim, Kim & Lim, 2015).

Clinicians recommend that PD patients use assistive devices to improve their gait and prevent falls. Traditionally, patients with mild symptoms use canes and those with severe symptoms use walkers. However, use of assistive devices during gait markedly reduces gait speed, and walkers more frequently induce freezing of gait (Cubo, Moore, Leurgans & Goetz, 2003; Bryant, Pourmoghaddam & Thrasher, 2011). Four-wheel walkers were found to significantly reduce stride length but had no significant impact on other gait parameters (e.g., cadence, proportion of double support, base of support, and support time) (Bryant et al., 2011). Assistive devices equipped with lasers were developed to improve freezing of gait and step length. Results regarding the effect of four-wheel walkers with lasers have been inconsistent, with one study showing that four-wheel walkers with lasers did not reduce freezing of gait (Cubo et al., 2003) but others suggesting otherwise. To address the inconsistency in the results and overcome the limitations of assistive devices, Kegelmeyer, Parthasarathy, Kostyk, White & Kloos (2013) compared the effects of five types of assistive devices (i.e., cane, standard assistive device, two-wheel walker, four-wheel walker, and U-Step walker) on gait parameters in 27 patients with PD. Their findings showed that all of the assistive devices except the four-wheel walkers and U-Step walkers significantly decreased gait speed. Gait variability was lowest with four-wheel walkers and highest with U-Step walkers, suggesting that U-Step walkers are associated with the highest risk of falling. Four-wheel walkers produced consistent improvements in all gait parameters, whereas lasers installed on U-Step walkers did not improve the gait parameters and were not safe.

Patients with PD who participated in the above study were aged 50 years or older and were capable of walking 10 m unassisted. It has been speculated that, in addition to these patients with PD, other patients with more mild or severe symptoms may also require assistive devices. Because Kegelmeyer et al. (2013) analyzed only the kinematic factors of gait, additional studies are needed to examine the distribution of foot pressure on the ground during gait because using assistive devices during gait would inevitably cause changes in foot pressure, which is in turn an important predictor of the risk of falling. Furthermore, as PD patients display severe gait deviations, examining coefficients of variation (CVs) during gait in patients using assistive devices could be conducive to identifying predictors of falls. The present study was conducted with the acknowledgement that the limitations of existing studies should be addressed via more systematic assessments of various gait assistive devices. The objective of this study was to identify the effects of assistive devices on patients with PD.

METHODS

1. Participants

Fifteen patients with PD in Hoehn and Yahr stage 3 (age: 62.3 ± 3.8 years; height: 167.3 ± 6.9 cm; weight: 65.3 ± 6.7 kg; time since onset: 6.5 ± 1.3 years) were enrolled in the study after obtaining informed consent from their guardians and physicians. In addition to having PD, the inclusion criteria were as follows: ability to walk unassisted; no angina pectoris or abnormal blood pressure; no complications such as neurologic impairment or an epileptic disorder; and no progressive inflammatory arthritis.

2. Measurements

The GAITRite system (CIR Systems Inc., Peekskill, NY, USA), the reliability and validity of which have been verified, was used to objectively assess spatiotemporal variables of gait and distribution of foot pressure (McDonough, Batavia, Chen, Kwon & Ziai, 2001). The GAITRite system is an electronic walkway (total area: 488 × 61 cm; active sensor area: 366 × 61 cm) with 48 × 384 sensors per 1.27 cm of diameter (total: 18,432 sensors). When the participant walks on the carpet, the sensors detect foot pressure and transmit the data to a computer connected via a serial interface cable. This system is portable and can be installed anywhere with a flat surface. One of the advantages of this system is that it is highly convenient, providing accurate and objective measurements even with just one walk (Kim, Choi & Lim, 2011).

3. Procedure

Before measuring, all examiners were trained regarding contents, time, and methods pertaining to the measurements. Particularly, to ensure consistency, one examiner was assigned to each parameter when measuring patients' height, body weight, and lower extremity length. Furthermore, we scheduled appointments flexibly in consideration of the distance patients had to travel to the lab to minimize waiting for an examination.

The participants took their medications 2 hours before the examination. We provided adequate explanations regarding the experimental procedure as well as demonstrations to all participants. They were also given one or two practice sessions. All measurements were taken with the patients barefoot. From approximately 5 m in front of the gait carpet, the participants began walking upon an oral cue until approximately 5 m past the gait carpet.

Because the participants of this study were in Hoehn and Yahr stage 3, controlling gait speed would have hindered natural gait motions and increased the risk of falling. Hence, the participants were told to walk at their most comfortable speed and were encouraged to maintain a consistent speed. This process was repeated three to five times, and three sessions with data closest to the mean were used for analysis. For safety and behavioral management, one examiner was instructed to walk along the participants within a range that would not directly interfere with the participants' gait.

A physical therapist (the research assistant of this study) trained the participants to walk using the gait assistive devices before the experiment. Training time varied for each participant, as the therapist trained each one until the assistive devices were being used accurately and safely. The assistive devices used for this experiment were a cane (Harvey Surgical Supply Co., Flushing, NY, USA) and a two-wheeled walker (Medline Industries, Mundelein, IL, USA) (Figure 1).

Figure 1. Cane (left) and 2-wheeled walker (right).

4. Data processing

The acquired spatiotemporal and foot pressure distribution data were processed with the GAITRite software (version 3.2b). The definition of variables and calculation methods suggested by Kim et al. (2011) and Titanova et al. (2004) were used in this study. The functional ambulation

Table 1. Temporal-spatial gait variables

Variable	No assistive device	Cane	Two-wheeled walker	p^*
Functional ambulation profile (%)	87.27 (11.43)	85.00 (12.95)	80.33 (15.54)	0.510
Step time (sec)	0.49 (0.04)	0.52 (0.04)	0.50 (0.05)	0.276
Cycle time (sec)	0.98 (0.07)	10.04 (0.10)	1.01 (0.12)	0.352
Single support time (sec)	0.35 (0.04)	0.36 (0.05)	0.34 (0.05)	0.634
Double support time (sec)	0.23 (0.03)	0.34 (0.04)	0.37 (0.04)	0.000, 1<2,3
Swing time (sec)	0.36 (0.03)	0.33 (0.03)	0.29 (0.04)	0.000, 1>3
Stance time (sec)	0.62 (0.06)	0.66 (0.08)	0.67 (0.09)	0.216
Swing time ratio (%)	36.97 (2.70)	36.14 (2.78)	33.56 (5.09)	0.115
Stance time ratio (%)	63.04 (2.70)	63.87 (2.78)	66.47 (5.07)	0.111
Distance between heel (cm)	11.16 (2.69)	8.93 (1.49)	7.22 (1.33)	0.001, 1<2,3
Cadence (steps/min)	123.29 (8.47)	109.06 (6.84)	111.47 (10.34)	0.002, 1>2,3
Velocity (cm/sec)	110.90 (17.88)	89.74 (5.63)	72.56 (12.20)	0.000, 1>2>3
Normalized velocity (Leg Length/cm/sec)	1.38 (.32)	0.91 (0.12)	0.80 (0.12)	0.000, 1>2>3
Step velocity (m/sec)	1.11 (0.24)	0.96 (0.25)	1.14 (0.23)	0.228
Step length (cm)	51.04 (11.73)	49.13 (8.81)	43.66 (8.66)	0.257
Stride length (cm)	108.87 (11.98)	88.99 (13.21)	77.82 (17.38)	0.000, 1>2>3
Toe-out angle (°)	9.86 (5.59)	11.59 (7.01)	10.81 (6.43)	0.824
Step/lower extremity ratio (cm/LL)	0.67 (0.09)	0.65 (0.07)	0.54 (0.09)	0.395

*Significance was considered at $p < 0.05$. Normal gait: 1; cane: 2; two-wheeled walker: 3.

profile, which was not defined in the studies cited here, is a parameter that enables researchers to objectively distinguish differences between healthy controls and patients (Kim et al., 2013). It is calculated based on the data obtained from the GAITRite system and patients' physical measurements. The CV was computed by dividing the standard deviation by the arithmetic mean (Kegelmeyer et al., 2013).

5. Statistical analysis

The objective of this study was to identify the effects of gait assistive devices on gait in 15 patients aged 50 years or older diagnosed with PD in Hoehn and Yahr stage 3. The study model was a one-way repeated-measures within-subject design with the use of a gait assistive device (three factors: use of a gait assistive device or use of a cane or two-wheel walker) as the independent variable. The dependent variables were spatiotemporal variables of gait (step time, swing time, step length, step width, and toe-out angle) and foot pressure distribution variables.

One-way analysis of variance was used to verify the differences in means among the study groups, and when a significant difference was shown, Tukey's test was performed as post hoc analysis. SPSS for Windows version 21.0 was used for the statistical analysis, and the significance level for hypothesis verification was $\alpha = 0.05$.

RESULTS

1. Spatiotemporal variables

Table 1 shows the spatiotemporal variables of gait in PD patients using different gait assistive devices.

There was a statistically significant difference in double support time ($p = 0.000$) among the temporal variables of gait. Post hoc analysis showed that patients using a cane or walker had a longer double support time compared with those who did not. There was a statistical difference in swing time ($p = 0.000$). Post hoc analysis showed that patients not using a gait assistive device had a longer swing time than those using a walker.

There was a statistically significant difference in distance between heels ($p = 0.001$). Post hoc analysis revealed that patients using a cane or a walker had a longer distance than those not using a gait assistive device. There was a statistically significant difference in cadence (strides per minute) ($p = 0.002$), and post hoc analysis showed that patients not using a gait assistive device had a greater cadence than patients using a walker. There was a statistically significant difference in velocity ($p = 0.000$). Post hoc analysis revealed that patients not using a gait assistive device had faster gaits than those using a cane or walker, and patients using a cane walked faster than those using a walker. There was a statistically significant difference in standardized velocity ($p = 0.000$). Post hoc analysis showed that patients not using a gait assistive device walked faster than patients using a cane or walker, and patients using a cane walked faster than those using a walker. There was a statistically significant difference in stride length (p = 0.000). Post hoc analysis showed a greater stride length in patients not using a gait assistive device compared with patients using a cane or walker and a greater stride length in patients using a cane compared with patients using a walker.

2. Foot pressure

Table 2 shows the distribution of foot pressure in the gaits of PD patients using different assistive devices. There was a statistically significant intergroup difference in lateral zone 5 (p = 0.038) in peak pressure time. Post hoc analysis showed that the time to peak pressure was prolonged in patients using a walker compared with that in patients not using a gait assistive device or using a cane. There was a statistically significant intergroup difference in time to peak pressure in lateral zone 6 (p = 0.047). Post hoc analysis showed that the time to peak pressure was prolonged in patients using a walker compared with that in patients not using a gait assistive device or patients using a cane. Furthermore, there was a statistically significant intergroup difference medial zone 11 (p = 0.047). Post hoc analysis showed that time to peak pressure was prolonged in patients using a walker compared with that in patients not using a gait assistive device or patients using a cane.

Table 3 shows the sum of pressures in each area, active area, and peak pressure during gaits of PD patients using different assistive devices. There was a statistically significant intergroup difference in pressure × time in the mid foot (p = 0.048), and post hoc analysis showed that pressure × time was greater in patients not using a gait assistive device and or using a cane than in patients using a walker.

Table 2. Peak pressure time

Variable	Peak pressure time (sec)			
	No assistive device	Cane	Two-wheeled walker	p^*
Lateral zones				
1	0.51 (0.12)	0.56 (0.06)	0.47 (0.16)	0.218
2	0.11 (0.03)	0.13 (0.04)	0.13 (0.04)	0.319
3	0.08 (0.04)	0.07 (0.04)	0.09 (0.04)	0.700
4	0.02 (0.03)	0.03 (0.04)	0.03 (0.03)	0.697
5	0.10 (0.03)	0.11 (0.03)	0.14 (0.03)	0.038, 1,2<3
6	0.09 (0.04)	0.10 (0.03)	0.13 (0.04)	0.047, 1,2<3
Medial zones				
7	0.16 (0.20)	0.16 (0.13)	0.18 (0.09)	0.941
8	0.11 (0.03)	0.13 (0.04)	0.14 (0.02)	0.102
9	0.11 (0.03)	0.13 (0.04)	0.15 (0.04)	0.077
10	0.10 (0.04)	0.13 (0.04)	0.14 (0.04)	0.063
11	0.10 (0.03)	0.11 (0.03)	0.15 (0.04)	0.008, 1,2<3
12	0.09 (0.03)	0.10 (0.03)	0.12 (0.04)	0.076

*Significance was considered for p < 0.05. Normal gait: 1; cane: 2; two-wheeled walker: 3.

Table 3. Pressure × time, active area, and peak pressure

Variable		No assistive device	Cane	Two-wheeled walker	p^*
Pressure × time	Rear foot	26.43 (7.76)	26.64 (7.49)	30.78 (9.10)	0.431
	Mid foot	28.60 (4.51)	28.94 (4.40)	23.34 (3.60)	0.012, 1,2>3
	Fore foot	44.97 (6.20)	41.55 (10.09)	45.94 (10.55)	0.535
Active area	Rear foot	41.08 (2.88)	41.05 (4.20)	40.18 (2.85)	0.804
	Mid foot	28.01 (2.88)	28.73 (2.44)	28.18 (1.73)	0.784
	Fore foot	30.93 (1.34)	30.40 (3.49)	30.59 (1.72)	0.875
Peak pressure	Rear foot	22.67 (7.93)	22.37 (5.96)	25.36 (8.41)	0.640
	Mid foot	27.97 (5.21)	28.81 (5.45)	24.31 (6.47)	0.209
	Fore foot	49.13 (6.74)	47.97 (8.66)	50.38 (10.28)	0.830

*Significance was considered for p < 0.05. Normal gait: 1; cane: 2; two-wheeled walker: 3.

Table 4 shows the CV of gait variables in patients using different assistive devices. There was a statistically significant intergroup difference in the CV of step time (p = 0.037). Post hoc analysis showed that patients using a walker had a lower CV than patients using a cane. There was a statistically significant intergroup difference in the CV of stride length (p = 0.041). Post hoc analysis showed that patients using a walker and patients not using a gait assistive device had a lower CV than patients using a cane. There was a statistically significant intergroup difference in the CV of swing time (p = 0.029). Post hoc analysis showed that patients using a walker had a lower CV than patients using a cane. There was no statistically significant difference in the CV of double support

(p = 0.395).

Table 4. Coefficients of variation for gait variables

Variable	Coefficient of variation			p^*
	No assistive device	Cane	Two-wheeled walker	
Step time	4.38 (1.39)	10.47 (2.76)	3.35 (0.25)	0.037, 2>3
Stride length	5.17 (1.02)	17.34 (5.13)	5.31 (1.14)	0.041, 1,3<2
Swing time	6.52 (1.67)	19.19 (5.61)	5.84 (1.64)	0.029, 2>3
Double support	11.31 (3.61)	19.57 (7.16)	14.9 (5.10)	0.395

*Significance was considered for $p < 0.05$. Normal gait: 1; cane: 2; two-wheeled walker: 3.

DISCUSSION

Assessment of various gait assistive devices for patients with PD would provide useful information for clinicians when recommending assistive devices for the PD patients and their guardians. The objective of this study was to identify the effects of gait assistive devices in PD patients. Our findings showed that double support time was longer in patients using a cane or a walker than in patients not using a gait assistive device. This is a result of the additional force required for handling a cane or a walker owing to the added weight (Kegelmeyer et al., 2013). In patients not using a gait assistive device, an increase of support time is generally a marker of an elevated risk of falling, as it indicates reduced balance (Chamberlin, Fulwider, Sanders & Medeiros, 2005; Kegelmeyer et al., 2013), however, an increase of support time in patients using assistive devices stabilizes gait motions, thereby preventing falls.

Gait velocity and standardized velocity were lower in patients using a cane or walker than in patients not using a gait assistive device, and the same parameters were lower in patients using a walker than in those using a cane. Furthermore, stride length was shorter in patients using a cane or walker than in patients not using a gait assistive device and was shorter in patients using a walker than in patients using a cane. The reason for this result is that the two wheels on a walker pose additional challenges in the smooth handling of a walker, and using assistive devices, such as a cane or walker, requires the user to perform two tasks simultaneously (i.e., walking and handling an assistive device that requires careful attention) (Mahoney, Euhardy & Carnes, 1992). In a study that examined the effects of the severity of PD on gait, Kim et al. (2013) reported that patients in Hoehn and Yahr stage 3 walked more slowly with shorter step length and wider step width but with greater toe-out angle than patients in Hoehn and Yahr stage 1 or 2 (Kim, Kim, Moon & Lim, 2014). As we examined only patients in Hoehn and Yahr stage 3, future studies should survey the differences in the effects of gait assistive devices varying stages of PD.

In terms of foot pressure distributions, patients using a walker showed a peak pressure at a later time than patients not using a gait assistive device or patients using a cane in lateral zones 5 (p = 0.038) and 6 (p = 0.047) as well as medial zone 11 (p = 0.047). This is presumed to be because although handling a walker poses an additional burden on the user compared with handling a cane or not using an assistive device for walking, a walker stabilizes the user's gait by promoting efficient use of the muscles for landing the foot and thrusting for take-off.

The CV for step time, stride length, and swing time were lower in patients using a walker than in patients using a cane. This provides important clinical implications because based on the previous finding that higher CV increases the risk for falls (Verghese, Holtzer, Lipton & Wang, 2009; Kegelmeyer et al., 2013, and the low CV in patients using a two-wheeled walker signifies that it has reduced the risk of falling.

Preventing falls is an important concern for patients with PD. Clinicians need to deliver useful information to patients regarding the use of assistive devices. The findings of our study suggest that using a two-wheeled walker lowers the risk of falling. Future studies should not only investigate additional motion tasks, such as changing directions, but also perform longitudinal analysis to identify the effects of the long-term use of assistive devices.

CONCLUSION

The objective of this study was to identify the effects of gait assistive devices in patients with PD. We found that double support time was longer in patients using a cane and patients using a walker than in patients not using a gait assistive device. Gait velocity and standardized velocity were lower in patients using a cane or a walker than in patients not using a gait assistive device and lower in patients using a walker than in patients using a cane. Stride length was shorter in patients using a cane or a walker than in patients not using a gait assistive device and shorter in patients using a walker than in patients using a cane. Furthermore, the CV for step time, stride length, and swing time was lower in patients using a walker than in patients using a cane. In conclusion, two-wheel walkers presented the most consistent advantages in preventing the risk of falling.

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