TURNING CHARACTERISTICS IN PATIENTS WITH PARKINSON'S DISEASE DURING TIMED UP AND GO

MinJi Son ·ChangHong Youm* ·MyeoungGon Lee ·YouKyung Kim ·JinHee Kim

Biomechanics Laboratory, University of Dong-A, Busan, Korea

This study aimed to investigate turning characteristics of patients with PD, using 3D analysis during the TUG test, to examine associations with the severity of PD. A total of 30 individuals performed the TUG test 10 patients with Hoehn and Yarh stages 2.5 and 3.0 PD (group I), 10 patients with H&Y stage 2.0 PD (group II), and 10 healthy elderly controls. Walking speed; step length; ROM of the hip, knee, and shoulder joint; foot clearance height; were significantly different between PD patients and controls. Step length and foot clearance height were significantly different between group I and group II. In conclusion, the TUG test may be a useful task for identifying turning characteristics of the severity of PD and to differentiate between PD patients and controls.

KEYWORDS: Parkinson's disease (PD), Timed Up & Go (TUG), kinematics, spatiotemporal variables, gait

INTRODUCTION: Patients with parkinison's disease experience movement impairments, such as tremors, rigidity, bradykinesia, flexed postures, and freezing of gait (Buckley, Pitsokoulis, & Hass, 2008; Jankovic, 2008). Further, PD patients experience considerable difficulty when walking and turning, and during complex motor and cognitive tasks (Camicioli, Oken, Sexton, Kaye, & Nutt, 1998; Morris, Morris, & Iansek, 2001). Thus, PD patients often experience falls and fall-related injuries, and suffer from a high rate of recurrent falling. However, previous studies have primarily compared PD patients and controls. Additionally, there remains a lack of generalized information regarding variables of gait in PD patients.
Timed Up and Go(TUG) test has been used as a measure of balance and mobility in elderly and PD patients during walking and turning tasks(Weiss et al., 2010; Zampieri et al., 2010). The TUG test is highly correlated with functional mobility, gait velocity, and falls in the elderly (Nocera, Roemmich, Elrod, Altmann, & Hass, 2013; Viccaro, Perera, & Studenski, 2011). However, the majority of studies have used manual clocks and accelerometers to obtain measurements during the TUG test (Weiss et al., 2010; Zampieri et al., 2010). In addition, variables in the TUG test have classically been limited to elapsed time and total steps; therefore, a wealth of information may be ascertained when using the TUG test in combination with 3D motion analysis systems. The purpose of this study was to investigate turning characteristics of patients with PD, using 3D analysis during the TUG test, in order to classify the severity of PD.

METHODS: This study enrolled a total of 30 subjects; 10 patients exhibiting Hoehn and Yarh stages 2.5 or 3.0 PD (group I), 10 patients exhibiting H&Y stage 2.0 PD (group II), and 10 elderly controls from a local elderly center, who were matched with respect to age. The inclusion criteria were: (a) diagnosis of idiopathic PD, (b) H&Y stages 2 to 3, (c) currently receiving anti-Parkinsonism medications, and (d) no cognitive impairment. Cognitive impairment was defined as any score on the Mini Mental State Exam [MMSE] < 24. Subjects with any impairment of the lower limbs within 6 months prior to the testing, those unable to walk unassisted, or exhibiting neurological disorders, were excluded. Experimental protocols were approved by the Institutional Review Board. All subjects provided written informed consent prior to participation.
The TUG test was captured by 6 infrared cameras (Vicon, MX-T10, UK) on an 8-meter walkway. A 39-marker Plug-in-gait model was used, according to the modified Helen Hayes Marker Set, with 14 mm spherical reflective markers. PD patients were tested in an off-medication state, after abstaining from anti-parkinsonism medications for a minimum of 12 hours prior to the trial. All subjects performed the TUG test as follows: patients were asked to

stand from a chair and walk 2.44 meters forwards, as marked by a circular cone, and then turn and return to the chair, before sitting down. Subjects were instructed to perform the test safely but as quickly as possible (Persson, Danielsson, Sunnerhagen, Grimby-Ekman, & Hansson, 2014). The turning phase was defined as the 2 steps immediately after the start of turning. Furthermore, the more affected side (MAS) and less affected side (LAS) was defined as the side exhibiting the greatest degree of PD symptoms. The sampling frequency for kinematic data was set at 100 Hz, with the collected data filtered using digital low-pass filters (2nd-order Butterworth filters) at 6 Hz. All spatiotemporal and kinematic variables were analyzed by averaging 3 trials.

All statistical analyses were performed using SPSS (version 21.0, SPSS Inc, Chicago, IL). Descriptive statistical analysis, using mean and standard deviation, was used to describe the characteristics of each variable. After confirmation of normality using the Shapiro-Wilk test, a repeated measures multi-way ANOVA was used to examine interactions and main effects between groups, and within steps and directions, during the turning phase. Moreover, 1-way ANOVA between groups, with Tukey's Honest Significant Difference post-hoc test, and t-tests for paired samples were used to determine significant differences. Significance was set at $p < 0.05$.

RESULTS: Walking speed, step length, range of motion (ROM) for the hip, knee and shoulder, foot clearance height, significantly differed between PD groups and controls. Additionally, step length and foot clearance height significantly differed between group I and group II. Furthermore, walking speed, step length, the ROM of the hip, knee, and shoulder, and foot clearance height significantly differed within steps and directions (Table 1).

DISCUSSION: In comparisons between individuals with and without PD, significant differences in walking speed; step length; ROM of the hip, knee, and shoulder joint; and foot clearance height were observed. Crenna et al. (2007) have shown with 3D analysis that walking speed is significantly different between PD patients and controls during the approached turning 90° task using patient-preferred walking speed. Yang et al. (2016) compared differences between PD patients and controls using a 3D motion capture system during the TUG test, with results showing significant differences in sagittal and frontal inclination angles, stride length, and stride time. These results might account for characteristics of hypokinesia in PD patients (Huxham, Baker, Morris, & Iansek, 2008), which is typified by difficulties with planning, initiating, and executing movement, and with performing sequential and simultaneous tasks (Jankovic 2008). Further, hypokinesia in PD patients might be associated with a decreased step length and walking speed (Roiz et al., 2010). The present study observed a significant difference in the ROM of the hip, knee, and shoulder joints between PD patients and controls; these results are in agreement with those observed previously. Additionally, reduced hip and knee ROM may lead to reduced step length. The hip and knee ROM may be the result of a reduction in foot clearance height; thus, variables detecting PD severity include step length and foot clearance height.

When examining results for the walking speed of the MAS and LAS steps, ROM of the hip and shoulder, and foot clearance height, it can be seen that groups I and II exhibited significant differences in all such cases. Controls were observed to have coordination between the MAS and LAS steps, regardless of the turning direction in the TUG test. Successful turning is defined as a reduction in stride length and ROM of the lower limb on the inside step, with a concomitant increase on the outside step (Orendurff et al., 2006). However, PD patients showed a reduction in step length, compared to controls, for both MAS and LAS steps. Individuals with PD typically exhibit turning characteristics such as en bloc turning, impeded craniocaudal sequence (Yang et al., 2016), and asymmetry of the lower limbs (Orendurff et al., 2006). PD patients in this study exhibited poorer coordination between steps in the MAS and LAS turning directions. En bloc turning is a technique whereby an individual reduces the dimensionality of the interconnected chain of axial segments, to create just 1 degree of freedom in order to compensate for hypokinesia (Bhatt, Pieruccini-Faria, & Almeida, 2013). These turning characteristics may lead to reduced ROM in the sagittal plane for the hip and knee, and a reduction in foot clearance height. Conversely, healthy controls tend to exhibit a pivoting strategy in turning movements, whereby the individual steps across their stance limb (Orendurff et al., 2006; Bhatt et al., 2013). Previous studies have also observed these phenomena, particularly that of en bloc turning to the MAS direction in group I, and to the LAS direction in group II.

Table 1. The results of spatiotemporal and kinematic variables during turning phase

Variables	Direction	Step	Group I	Group II	Controls	F	Post-hoc
Walking speed (m/s)	MAS	MAS	0.58 ± 0.21	0.60 ± 0.18	0.70 ± 0.17	1.235	NS
		LAS	0.59 ± 0.20	0.60 ± 0.18	0.90 ± 0.12#	10.426*	C > II, I
	LAS	MAS	0.53 ± 0.16	0.69 ± 0.22	0.96 ± 0.15¶	13.980*	C > II, I
		LAS	0.52 ± 0.16¶	0.70 ± 0.22	0.63 ± 0.11#,¶	2.773	NS
Step time (s)	MAS	MAS	0.44 ± 0.06	0.48 ± 0.06	0.44 ± 0.05	1.527	NS
		LAS	0.49 ± 0.09#	0.48 ± 0.05	0.43 ± 0.05	2.476	NS
	LAS	MAS	0.46 ± 0.06¶	0.49 ± 0.05	0.44 ± 0.05	1.488	NS
		LAS	0.45 ± 0.07	0.47 ± 0.05	0.45 ± 0.06	0.655	NS
Step length (m)	MAS	MAS	0.33 ± 0.07	0.44 ± 0.09	0.33 ± 0.08	6.129*	II > I, C
		LAS	0.32 ± 0.07	0.36 ± 0.09#	0.39 ± 0.08	1.651	NS
	LAS	MAS	0.28 ± 0.07¶	0.42 ± 0.13	0.40 ± 0.13	4.861*	II > I
		LAS	0.33 ± 0.08#	0.42 ± 0.07¶	0.32 ± 0.08	4.962*	II > I, C
ROM of hip (°)	MAS	MAS	28.41 ± 5.78	30.60 ± 9.45	35.55 ± 7.15	2.358	NS
		LAS	30.78 ± 4.89	29.97 ± 8.97	34.69 ± 7.21	1.218	NS
	LAS	MAS	30.00 ± 5.63	31.78 ± 6.95	37.11 ± 5.43	3.753*	C > I
		LAS	30.11 ± 8.38	30.57 ± 7.91	32.15 ± 5.95#	0.204	NS
ROM of knee (°)	MAS	MAS	47.13 ± 10.50	45.47 ± 12.78	59.21 ± 8.47	4.888*	C > I, II
		LAS	50.47 ± 5.26	46.64 ± 9.66	55.06 ± 7.00	3.135	C > II
	LAS	MAS	44.75 ± 7.14	47.44 ± 9.96	52.15 ± 4.83	2.429	NS
		LAS	50.95 ± 11.39#	48.72 ± 8.80	59.61 ± 8.69#	3.513*	C > II
ROM of ankle (°)	MAS	MAS	21.68 ± 5.51	23.32 ± 9.90	27.56 ± 13.28	0.907	NS
		LAS	23.26 ± 4.66#	22.11 ± 5.38	23.89 ± 5.54	0.301	NS
	LAS	MAS	21.34 ± 5.10	23.78 ± 7.24	25.89 ± 5.45	1.438	NS
		LAS	22.66 ± 6.33	21.10 ± 3.18	22.83 ± 4.86	0.058	NS
ROM of shoulder (°)	MAS	MAS	13.72 ± 5.71	18.83 ± 9.67	26.44 ± 14.91	3.526*	C > I
		LAS	20.06 ± 9.33#	25.08 ± 11.73	30.49 ± 15.65	1.738	NS
	LAS	MAS	16.14 ± 7.08	20.14 ± 9.98	36.92 ± 15.77	9.145*	C > II, I
		LAS	17.68 ± 7.35	23.08 ± 10.18	24.66 ± 11.82	1.352	NS
Foot clearance height (cm)	MAS	MAS	14.28 ± 3.51	17.58 ± 3.66	19.65 ± 1.92	7.477*	C > I
		LAS	16.71 ± 2.60#	19.44 ± 2.28#	21.25 ± 2.02#	9.727*	C, II > I
	LAS	MAS	18.70 ± 7.03	19.96 ± 2.74¶	22.04 ± 2.09¶	1.392	NS
		LAS	14.20 ± 3.17¶	18.32 ± 2.80¶	19.47 ± 2.28¶	9.963*	C, II > I

All data are given as mean ± standard deviations. MAS: more affected side, LAS: less affected side, ROM: range of motion, I: group I, II: group II, C: controls. *: Denotes significant difference between groups ($p < 0.05$), #: Denotes significant difference between steps ($p < 0.05$), ¶: Denotes significant difference between turning directions ($p < 0.05$).

CONCLUSION: TUG test may be a useful task for identifying turning characteristics of the MAS and LAS side, the severity of PD, and as a method to differentiate between PD patients and controls.

REFERENCES:

Bhatt, Pieruccini-Faria, & Almeida, 2013). Dynamics of turning sharpness influences freezing of gait in Parkinson's disease. *Parkinsonism & Related Disorders, 19(2)*, 181-185.

Camicioli, R., Oken, B. S., Sexton, G., Kaye, J. A., & Nutt, J. G. (1998). Verbal fluency task affects gait in Parkinson's disease with motor freezing. *Journal of Geriatric Psychiatry and Neurology, 11(4)*, 181-185.

Crenna, P., Carpinella, I., Rabuffetti, M., Calabrese, E., Mazzoleni, P., Nemni, R., & Ferrarin, M. (2007). The association between impaired turning and normal straight walking in Parkinson's disease. *Gait & Posture, 26(2)*, 172-178.

Huxham, F., Baker, R., Morris, M. E., & Iansek, R. (2008). Footstep adjustments used to turn during walking in Parkinson's disease. *Movement Disorders, 23(6)*, 817-823.

Jankovic, J. (2008). Parkinson's disease: clinical features and diagnosis. *Journal of Neurology, Neurosurgery & Psychiatry, 79(4)*, 368-376.

Morris, S., Morris, M. E., & Iansek, R. (2001). Reliability of measurements obtained with the Timed "Up & Go" test in people with Parkinson disease. *Physical therapy, 81(2)*, 810-818.

Nocera, J. R., Roemmich, R., Elrod, J., Altmann, L. J., & Hass, C. J. (2013). Effects of cognitive task on gait initiation in Parkinson disease: evidence of motor prioritization. *Journal of Rehabilitation Research & Development, 50(5)*, 699-708.

Orendurff, M. S., Segal, A. D., Berge, J. S., Flick, K. C., Spanier, D., & Klute, G. K. (2006). The kinematics and kinetics of turning: limb asymmetries associated with walking a circular path. *Gait & Posture, 23(1)*, 106-111.

Persson, C. U., Danielsson, A., Sunnerhagen, K. S., Grimby-Ekman, A., & Hansson, P. O. (2014). Timed Up & Go as a measure for longitudinal change in mobility after stroke–Postural Stroke Study in Gothenburg (POSTGOT). *Journal of Neuroengineering and Rehabilitation, 11(1)*, 83.

Roiz, R. D. M., Cacho, E. W. A., Pazinatto, M. M., Reis, J. G., Cliquet Jr, A., & Barasnevicius-Quagliato, E. (2010). Gait analysis comparing Parkinson's disease with healthy elderly subjects. *Arquivos de neuro-psiquiatria, 68(1)*, 81-86.

Viccaro, L. J., Perera, S., & Studenski, S. A. (2011). Is timed up and go better than gait speed in predicting health, function, and falls in older adults? *Journal of the American Geriatrics Society, 59(5)*, 887-892.

Weiss, A., Herman, T., Plotnik, M., Brozgol, M., Maidan, I., Giladi, N., & Hausdorff, J. M. (2010). Can an accelerometer enhance the utility of the Timed Up & Go Test when evaluating patients with Parkinson's disease? *Medical Engineering & Physics, 32(2)*, 119-125.

Winogrodzka, Wagenaar, Booij, & Wolters, 2005. Rigidity and bradykinesia reduce interlimb coordination in Parkinsonian gait. *Archives of physical medicine and rehabilitation, 86(2)*, 183-189.

Yang, W. C., Hsu, W. L., Wu, R. M., Lu, T. W., & Lin, K. H. (2016). Motion analysis of axial rotation and gait stability during turning in people with Parkinson's disease. *Gait & Posture, 44*, 83-88.

Zampieri, C., Salarian, A., Carlson-Kuhta, P., Aminian, K., Nutt, J. G., & Horak, F. B. (2010). The instrumented timed up and go test: potential outcome measure for disease modifying therapies in Parkinson's disease. *Journal of Neurology, Neurosurgery & Psychiatry, 81(2)*, 171-176.

Acknowledgements

This study was supported by the Dong-A University research fund.