

Original Article

Differences in obstacle avoidance between healthy and Parkinson's disease people

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Abstract

The purpose of this study was to investigate the electromyographic, kinematic and force differences in obstacle avoidance between healthy and people with Parkinson disease. **Methods:** Eight healthy participants served as control group (CG) and eight patients with Parkinson's disease (PD) performed trials for three tasks: free walking and obstacle crossing for heights located in a height of 0%, 10% and 20% of their respective leg length. Contact time, relative vertical ground reaction force, foot distance before and after obstacle, obstacle clearance and joint flexion over obstacle and the agonist activity of the plantar flexors were evaluated. **Results:** The results demonstrated that PD patients had longer contact time and time of clearance, while they developed lower, relative vertical ground reaction forces, obstacle clearance and joint flexions over the obstacle compared to CG. The agonist activity was lower in PD patients. **Conclusions:** The above obtained results suggest that PD patients have a deficit in passing over a stable obstacle and this could be attributed to the inability of their neuromuscular system to control motion while performing complex gross motor tasks.

Key Words: Parkinson disease; obstacle avoidance; ground reaction forces; EMG; kinematics

Introduction

The main characteristic of PD movement is the hypokinesia which in gait movement is characterised by slow velocity and small steps with double support being prominent (M. Morris, Iansek, McGinley, Matyas, & Huxham, 2005). An usual problem in the life of PD people is that they have difficulties in dealing various natural obstacles such as small boxes, abnormal surfaces, pavements etc. Due to this fact, a high number of tripping has been reported which leads in falls and consequently in injuries. According to a previous study (Stolze et al., 2004), 62% percent of the people with PD have been experienced tripping and falling. A 27% of them will have a hip fracture in the first 10 years after the diagnosis of PD (Johnell, Melton, Atkinson, O'Fallon, & Kurland, 1992). For this reason the investigation on the movement strategy of PD people is a crucial point to understand the reasons of tripping of this people. However this field of study is relatively scarce.

Generally speaking the main conclusion for obstacle avoidance during obstacle crossing is the optimal placement of the foot in front and after the obstacle because the location of the foot close or far may cause contact with the obstacle and consequently falling (Chou & Draganich, 1998).

Relevant studies on this issue reported two cases of obstacle avoidance. One type is related with moving obstacle (Dietz & Michel, 2008; Snijders et al., 2010; van Hedel, Waldvogel, & Dietz, 2006) while the other type is related with stable obstacle (Vitorio, Pieruccini-Faria, Stella, Gobbi, & Gobbi, 2010). These studies reported that PD individuals demonstrated reduced step length and velocity compared with healthy people, which are predictors of tripping during obstacle avoidance. However, both PD and control groups demonstrated the same height of clearance. Contrarily, it has been reported that PD individuals demonstrated lower clearance compared to healthy ones (Kotzamanidou et al., 2009).

Revising all the above mentioned studies (Galna, Murphy, & Morris, 2010; Vitorio, et al., 2010) it was found that they did not analyze the joints flexion of the lower limb over the obstacle which are also predictors for optimal clearance, neither the agonist activity during obstacle crossing.

Based on the above mentioned data, the purpose of this study was to re-examine the effect of obstacle height in PD clearance movement. Part of this study has been published elsewhere (Kotzamanidou, et al., 2009).

Material & methods

Participants/Procedure/Test protocol

Sixteen individuals, including 8 people with Parkinson Disease (PD) and 8 people serving as control group (CG) participated in the study. All the characteristics of participants are presented in Table 1. The Hoehn

and Yahr stage (Hoehn and Yahr 1967, Folstein 1975) of the PD patients was I or II and the duration of the disease for the PD patients ranged from 3 months to 3 years. Patients with other neurological problems, with acute medical problems that could affect gait and with a score below 24 at the Mini Mental State Examination (MMSE) were excluded. The subjects participated in the study voluntarily and signed an informed consent. All the experiments took place in the laboratory of Coaching and Sport performance of the Department of Sports Science and Physical Education of the Aristotle University. The experiment was performed according to Ethics of the

Aristotle University, Thessaloniki, Greece.

When participants arrived in the laboratory they were verbally informed about the procedure and then they signed a written consent. After that they were familiarized with the environment of the laboratory and then the anthropometric data were collected (*i.e.* body height, weight, knee and ankle width) for the data required for the motion analysis data processing, and for the calculation of the percentage of body fat. Subjects having body fat more than 30% were excluded because this percentage ensures the validity of EMG recording. In addition, from the study were excluded people who had neurological disorders which possibly affected their performance. After the acquisition of the anthropometric characteristics, the subjects performed a general warm up including low intensity running on a treadmill for five minutes and warming up exercises for the lower limb. The markers and the EMG electrodes were attached followed afterwards. The participants were instructed to walk on their preferred speed along an 8-meter walkway with an obstacle on the midway. In addition, they were instructed to locate the foot on the force plate once in front of the obstacle. The participants started walking by the verbal instruction go. Totally they performed eight trials for each condition and finally five trials were averaged for each obstacle height for further analysis.

Instrumentation

Kinematic data were captured using a six-camera 3D motion analysis system (VICON 612, Oxford Metrics Ltd, Oxford, Oxfordshire, UK), sampling at 100Hz. Sixteen reflective markers (2.5 cm diameter) were placed over specific landmarks on the lower limbs and pelvis. More specifically, four markers were placed on the pelvis (anterior and posterior superior iliac spines) and bilaterally one on the thigh laterally, on the lateral epicondyle, on the middle of the shank laterally, on the heel, on the lateral malleolus and between the third and forth phalanges of the foot. One additional marker was placed on the obstacle which consisted of a light-weight, thin, plastic tube. The obstacle was placed perpendicular to the direction of walking, and parallel to the ground. The height of the obstacle was set in a random order at 0%, 10%, or 20% of the lower limb length of each participant (Vitorio, et al., 2010).

The ground reaction forces (GRF) of the trailing foot were captured with a ground mounted 40×60 cm force-plate (Bertec Type 4060, Bertec Corporation, Columbus, OH, USA), which was placed along the pathway of the subject. Prior every session the dynamometer, the force-plate and the motion analysis system were calibrated according to the manufacturers' instructions.

The EMG activity was recorded with a BTS Telemg EMG device (Milano, Italy), using bipolar surface Ag/AgCl electrodes (contact surface 0.8 cm, inter-electrode spacing 2 cm). The signal was preamplified (1,000x). The sampling frequency for the EMG and the ground reaction force signals was set at 1 kHz. The amplifier had common-mode rejection ratio greater than 110 dB at 50/60 Hz and the gain was 1000 at a bandwidth from 10 to 500 Hz. For the EMG evaluation electrodes were located in m. gastrocnemius and soleus muscle. The electrode placement was according to the SENIAM guidelines (Hermens et al., 1999). Prior to electrode placement the skin was carefully dry-shaved, rubbed with sandpaper, and cleaned with an alcohol solution. This preparation resulted skin impedance below 5kΩ. The ground electrode was set over the medial malleolus of the contra lateral foot.

The analog signals of the EMG and force-plate were converted to digital (16 bit) and stored for further analysis. The data acquisition board of the VICON system was responsible for the synchronization of all signals. The sampling frequency was set at 1 kHz. Finally, one analog caliper (Lafayette Instrument Co. Lafayette, Indiana, USA) was used for the measurement of the skinfolds and the estimation of body fat mass.

Table 1: Demographic and anthropometric characteristics [Mean ± standard deviation] of the participants (n=16, 8/8)

Age (in years)	Parkinson Control Group	74.1±8.1 64.6±3.6
Body mass (in kg)	Parkinson Control Group	73.7±11.8 79±11.9
Body fat (in % of body mass)	Parkinson Control Group	20.8±3.3 19.6±2
Body height (in m)	Parkinson Control Group	1.78±0.06 1.75±0.05
Lower limb length (in m)	Parkinson Control Group	0.89±0.04 0.87±0.07

Data reduction

Kinetics

Offline data processing was required to calculate the outcome variables using Matlab scripts (Matlab 7.0, Mathworks Inc.). For the GRF, the peak for the vertical propulsive component was analyzed. All values were normalized to the body weight. Furthermore, contact times during the stance phase of trailing limb and duration of leading limb swing phase were recorded. The onset and offset of the GRF defined the duration of the stance phase and the threshold was defined as 20 N.

Kinematics

The maximal hip, knee and ankle joint flexion (in the sagittal plane) of leading limb were calculated during the obstacle crossing. Regarding crossing phase, trailing and leading limb placement in front and just after the obstacle were calculated. In addition to this, step length (horizontal distance from the calcaneus marker of the trailing limb to the calcaneus marker of the leading limb at the instance of its touchdown on the ground) was estimated. Additionally, the vertical height distance of leading and trailing limb over the obstacle was calculated from the distance of leading limb to ground. All trajectories were filtered using the internal splines function of the VICON system whereas the end of the gait cycle was determined using the kinematic data of the limb. Figure 2 depicts the main timing periods recorded during the crossing phase for the leading and trailing limbs.

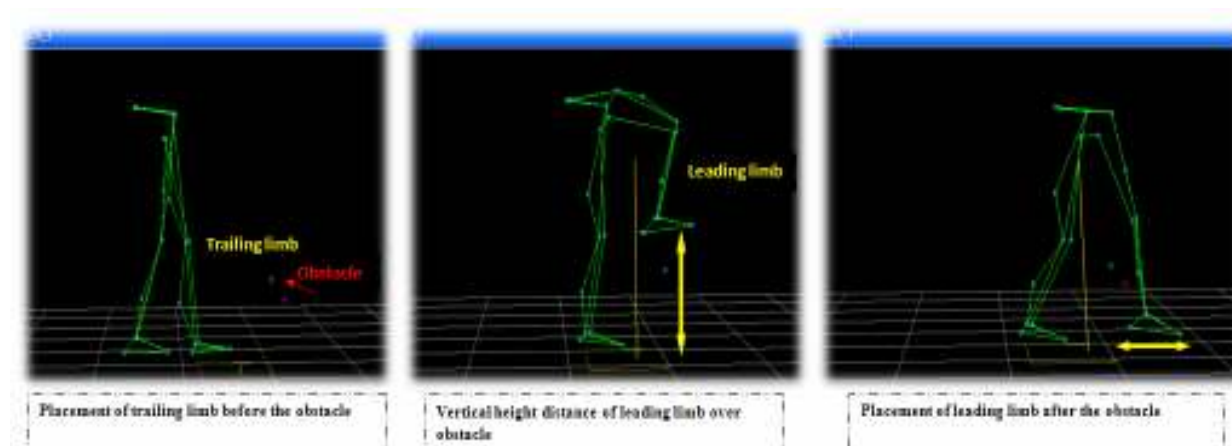


Figure 2. Representation of main dependent variables at the crossing phase for the leading and the trailing limbs.

Electromyography

The EMG amplitude was then normalized to the average value of each stride for the respective muscle and subject and expressed as percentage of the mean (Patikas et al., 2007). In addition to this, the normalized EMG was computed for each of the following phases according to kinematics depiction: the stance phase, defined as the period from initial contact till toe-off (stance phase) and the swing phase defined as the period from toe-off till the subsequent heel strike (Kellis & Liassou, 2009). Data were further processed offline using Matlab scripts.

Statistics

Descriptive statistics (mean values $\pm$ standard deviation) were calculated for all dependent variables. Between-group differences and the effect of the obstacle height were examined with a two-way 2x3 (2 groups and 3 conditions) ANOVA with repeated measurements in the second factor. The level of significance was set at an alpha level of $p < 0.05$. All statistical analyses were undertaken using SPSS 17 statistical software (SPSS Inc., Chicago, IL, USA).

Results

The maximum flexion joint angles of the hip, knee and ankle for the leading limb are presented in Figure 1. Maximal angles of the above mentioned joints increased significantly in both groups when increasing the obstacle height ($p < 0.05$). Significant differences were presented between groups across all conditions as the CG showed greater ankle, knee and hip flexion compared to PD participants.

During the impulse phase, ANOVA revealed a longer contact time period of trailing limb in all examined conditions in participants with PD compared to CG ($p < 0.01$). The same occurred for the variable swing phase of leading limb, as participants with PD presented elongated swing phase duration compared to control participants and in the three conditions ($p < 0.01$). In addition to this, people with PD demonstrated lower

values of vertical ground reaction forces of the trailing-support limb compared to control ones and this was revealed in all obstacle conditions ($p < 0.05$). All the above results are gathered in Table 2.

Regarding obstacle crossing, CG presented higher vertical height distance of leading limb over obstacle at the three examined conditions compared to PG. The same occurred for the trailing limb in all three conditions ($p < 0.05$). Differences between groups were observed for leading limb placement after the obstacle and trailing limb placement in front of the obstacle. People with PD placed the trailing limb nearer to the obstacle marker and the same group placed the leading limb nearer just after the obstacle marker but only for the 10% and 20% obstacle conditions ($p < 0.05$). As a result, people with PD demonstrated shorter step length compared to control group ($p < 0.01$) (Table 2).

Finally, PD revealed lower values of EMG agonist activity of the gastrocnemius and soleus muscle compared to control's group participants ($p < 0.05$).

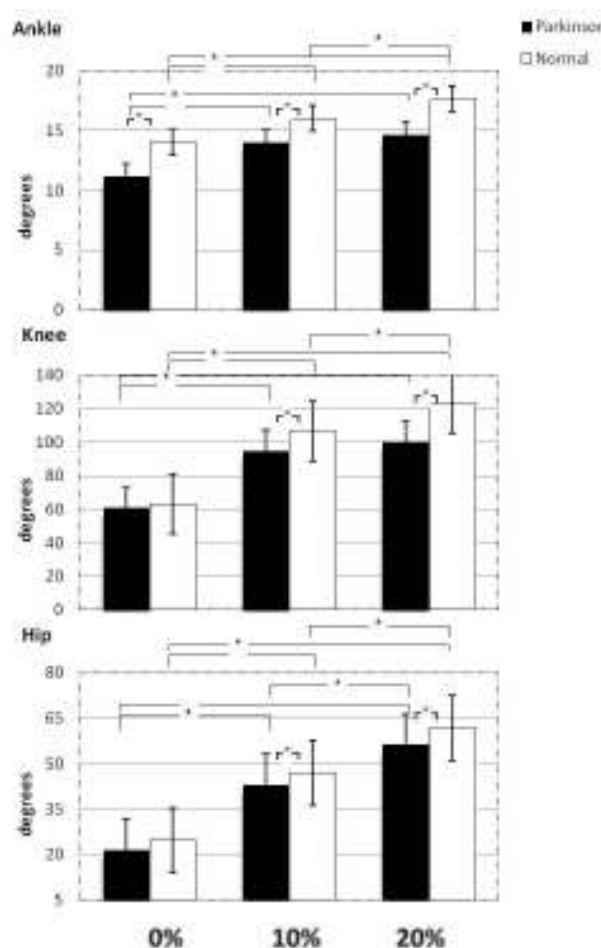


Figure 1. Maximum flexion joint angles (sagittal plane) for the leading limb in people with PD and in control group. Asterisks indicate statistical significance ($p < 0.05$).

Discussion

The obtained results indicate that the PD group had a shorter and slower obstacle clearance compared to CG. Lower was also the height of clearance, the propulsive forces and the agonist activity during contact time. However they demonstrated higher antagonist activity. The obtained data indicate that PD group set their feet closer their foot to the obstacle before and after the clearance while their velocity of clearance was slower compared with CG. These findings are in agreement with previous studies related with obstacle avoidance of people with PD (Vitorio, et al., 2010). According to the existed literature, the obtained data predict a non optimal obstacle crossing or even more tripping. Actually the obtained data and previous ones confirm the findings for the height clearance because PD demonstrated lower height clearance without any tripping in all of the three conditions. These findings contrast to previous relevant studies which found similar clearance height between PD and CG (Vitorio, et al., 2010). The previous mentioned studies supported their findings that the presence of obstacle may be a cue for stride length increase as it reported earlier (Rubinstein, Giladi, & Hausdorff, 2002)

Generally speaking (Cunnington, Iansek, Bradshaw, & Phillips, 1995; Georgiou et al., 1993; M. E. Morris, Iansek, Matyas, & Summers, 1996; M. E. Morris, Matyas, Iansek, & Summers, 1996), Parkinson disease is caused due to the impairment of Basal Ganglia function. Basal Ganglia contribution is considered that via

Supplementary Motor Area connection, control complex movements controlling activation and deactivation of sub movement within the total movement sequence and using sensory information optimize the motor performance. Sensory cues (acoustic, vision) seem to be an effective mean for dopamine circumvention but **until** now is not precisely known the exact mechanism which causes this effect. However reviewing the relevant literature deeply, we must comment the following. That the vision cues which improve stride length under specific condition. Firstly the lines must be located on the floor in only parallel and horizontally and not vertically. The vision cues must have specific dimensions and color to differentiate them from the color of surrounding. Besides this vision cueing affect also stride velocity (Rubinstein, et al., 2002) while the afore mentioned studies reported that their subjects though demonstrated equal obstacle clearance their step clearance was slower. On the opposite in our study both clearance velocity and height were inferior in PDG. More over the afore mentioned studies (Galna, et al., 2010) used bright yellow color while in our study silver metallic one. Besides they found that during support phase PDP developed higher mediolateral instability. All the above mentioned indicate that the height clearance of an obstacle needs further research.

However our obtained data regarding propulsive force and EMG activity support further our height clearance finding. Specifically propulsive forces were higher in all cases in CG compared to PDP. This case may be supported by previous studies which found that PDP during gait develop lower push of forces (Sofuwa et al., 2005). Interestingly all groups showed a tendency to increase their forces with obstacle height increase been in agreement with relevant study related with adults (Lu, Chen, & Chiu, 2012). Higher agonist activity was observed in CG in all conditions of obstacle crossing. This findings could be partially be supported by previous studies which found that PDP develop lower activity during gait due to their weakness and impairment in their motor system (Gantchev, Viallet, Aurenty, & Massion, 1996; Halliday, Hely, Reid, & Morris, 2008; Halliday, Lees, & Stern, 2011).

Table 2: Mean values and standard deviation of examined variables in the three obstacle conditions.

		0%	10%	20%	
Contact time during stance phase of trailing limb (ms)	Parkinson	898±118 *	1287±241 **	1492±515 ***	a,b,c
	Control Group	751±70	907±117	990±137	a,b,c
Swing phase duration of leading limb (ms)	Parkinson	610±139 **	883±197 **	1117±116 ***	a,b,c
	Control	480±78	622±74	718±99	a,b,c
Peak vertical ground reaction force (times body weight)	Parkinson	1.15±0.20 *	1.26±0.20 *	1.38±0.16 *	a,b,c
	Control Group	1.24±0.20	1.36±0.22	1.47±0.23	a,b,c
Placement of trailing limb before the obstacle	Parkinson	22.8±10.3 **	27.9±6.4 *	33.4±4.3 *	a,b,c
	Control Group	27±4.9	38±3	40.5±1.9	a,b
Placement of leading limb after the obstacle	Parkinson	31.6±4.1	29.7±11.1 *	26.4±7.8 **	b,c
	Control Group	32.9±11.2	38.2±5	35.6±1.7	a,b
Step length	Parkinson	54.4±13.3 *	57.5±15.2 **	59.8±10.5 **	b
	Control Group	59.9±12.8	76.2±5.4	76.1±3	a,b
Vertical height distance of leading limb over obstacle	Parkinson	19.1±2.3 *	26.1±1.8 *	37.2±4.6 **	a,b,c
	Control Group	21.3±1.9	31.1±2.4	45.2±2.9	a,b,c
Vertical height distance of trailing limb over obstacle	Parkinson	20.6±2.0	23.8±4.4 *	37.2±4.6 ***	a,b,c
	Control Group	22.8±2.3	32.5±7.0	47.5±6.0	a,b,c
EMG amplitude of M. Gastrocnemius during stance phase (normalized to maximum value)	Parkinson	0.19±0.03 *	0.20±0.03 *	0.23±0.06 **	b,c
	Control Group	0.26±0.02	0.25±0.04	0.27±0.06	
EMG amplitude of soleus during stance phase (normalized to maximum value)	Parkinson	0.16±0.03 **	0.19±0.02 *	0.21±0.05 **	a,b,c
	Control Group	0.23±0.03	0.23±0.04	0.25±0.04	a

*, **, ***: significant difference between people with parkinsonism and control ones ($p<0.05$, $p<0.01$, and $p<0.001$, respectively)

a,b,c: significant difference between 0% and 10%, 0% and 20%, and 10% and 20%, respectively ($p<0.05$)

Conclusions

In conclusion, the key findings of this survey indicate that the stable optical obstacle is not a parameter to facilitate movement, as in the passing of a sudden obstacle. Even the passing of such an obstacle could be an additional factor of falls, due to the placement of the foot closest to the obstacle and at a lower height than needed for passing over the obstacle

Conflict of interest statement

None declared.

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