Research Article

An Assessment of Gait Spatiotemporal and GRF of Parkinson Patients

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Abstract | The aim of this study was to assess the ground reaction force characteristics of patients with Parkinson's disease (PD) and to compare with healthy age group. A total of 14 patients with PD and 16 normal elderly subjects with matched age and gender were included in the study. A motion analysis system (Vicon Motion Analysis System) and two Kistler force plates were used to measure forces applied on the legs. Data were evaluated using independent t-test with significant point set at $p< 0.05$. There was no difference in cadence between left and right of normal subjects and those with PD. However, there was a significant decrease in walking speed and stride length in both sides of PD patients compared to normal subjects. Patients with PD showed a significant decrease in progression force and the second peak of vertical force. These subjects have to decrease their walking speed and increase their double limb support percentage to improve dynamic stability and decrease the magnitude of destabilizing forces. The mean values of propulsive component of anteroposterior force and the second peak of vertical ground reaction force decreased significantly due to performance of ankle joints plantar flexor which decreased in this group of subjects.

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Introduction

Parkinson's disease (PD) results from degeneration of the brain cells and reduction in dopamin enzyme (Roland et al., 2013). Although the prevalence of the disease is slightly lower in Asian than in western country (Muangpaisan et al., 2008), the prevalence of this disease is the same across European countries (von Campenhausen et al., 2005). It has been reported that in Europe, 1% populations above 60 years old have PD and tremor in their hands (Roland et al., 2013). Decrease in movement (Roland et al., 2013), decrease in static and dynamic stability are some symptoms associated with PD. Moreover, these subjects carry several problems during walking. Based on the results of various research studies, individuals with PD have reduced walking speed (Roiz et al., 2010; Rossi-Izquierdo et al., 2013; Strambi et al., 2004), reduced in range of motion of lower limb joints (Morris et al., 1999) and swing drag (Galna et al., 2010). The risk of falling is high in this group of subjects due to instability during walking (Amador et al., 2006; Cheng et al., 2014; Delval et al, 2013). Rossi-Izquierdo et al. (2013) observed that patients with PD have increased double support and decreased single limb stance phase and reduce walking speed.

In a study performed by Nigg and Skleryk (1988) it was shown that the peak of vertical force applied on the leg in the middle of stance phase in elderly subjects was more than that of younger subjects. Moreover, they reported a correlation between the magnitudes of anteroposterior force (breaking and progression components) with walking speed. Scott et al, studied the pattern and magnitudes of loads applied on the legs in subjects with peripheral vascular disease (Scott-Pandorf et al., 2007). Based on their results, the progression force of these subjects decreased due to weakness of plantar flexor muscles or use of a mechanism to control pain. However, Turns et al. (2007) observed that there was no difference between the progression force in subjects with hemiparesis. Although there are some studies on the forces applied on the leg in patients with various neurological disorders, there remain to investigate the asymmetry of force in subjects with Parkinson disease.

Very few studies have been performed on the comparison of breaking force of normal and those with PDs. Therefore, the aim of this research was to study the kinetic parameters during walking of subject with Parkinson's disease. Moreover, it was aimed to find the asymmetry of the loads applied on the leg in this group of subjects. The main hypothesis associated with this study was that the magnitude of loads applied on the legs in subjects with PD was the same as that of normal subjects.

Table 1: *The mean values of anthropometric data of the control and Parkinson groups*

Variable	Control M±SD	Parkinson M±SD	P-value
Age	61.37±8.00	64.00±7.79	0.37
Height(m)	1.66±0.07	1.65±0.07	0.72
Weight(kg)	70.31±10.26	65.29±10.34	0.19
BMI	25.60±3.07	24.08±3.55	0.22
Leg length(cm)	88.66±5.86	87.50±4.91	0.16

Material and Methods

Two groups of normal and those with PD were recruited in this study. They were matched based on age and gender. Table 1 shows the characteristics of the subjects participated in this study. Ethical approval was received from Ethics Committee of Hamedan University of Medical Sciences, Hamedan. Written informed consent was obtained from each subject before data collection. The main inclusion criteria to select the patients included:

1. Age varied between 50 and 70 years
2. Severity of Parkinson varied between II and III based on Yahr and Hohen scale (Hoehn and Yahr, 1998).
3. Having no auditory problems.
4. With no musculoskeletal and neurological surgery

Patients with PD were diagnosed based on the mentioned criteria and referred to the investigators by a neurologist from Hamedan Neurological Disease Center.

A motion analysis system (Vicon Motion Analysis System) and two Kistler force plates (400*600mm) were used to measure the forces applied on the legs. The data were collected with a frequency of 100 Hrz. A low pass filter (Butterworth) was used to filter the data with a cut off frequency of 10 Hz. The subjects were asked to walk with a comfortable speed to collect five successful trials. The mean values of 5 trials were used for each parameter. The main parameters included in this study were spatiotemporal gait parameters (walking speed, stride length, cadence, double and single limb support time), the peaks of the force applied in vertical direction (Fz1, Fz2, Fz3), medio-lateral direction (Fy) and antero-posterior direction (Fx) (Figure 1).

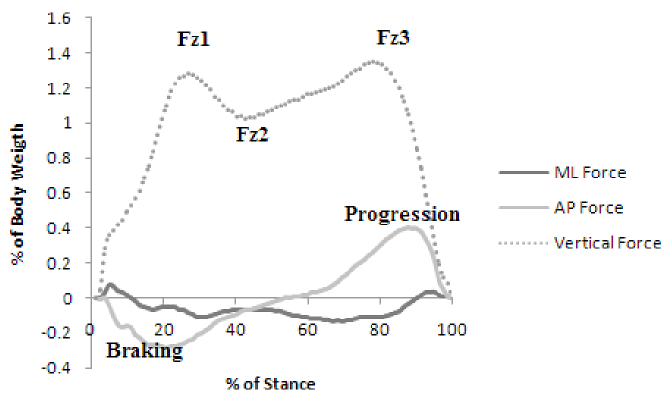

Figure 1: *The peaks of the forces selected in this study*

Statistical analysis

The difference between mean values of each parameters of normal and the patients was evaluated using T-test with significant point of < 0.05.

Results

The mean values of spatiotemporal gait parameters of

Table 2: *The mean values of spatiotemporal gait parameters of the control and Parkinson group*

Spatiotemporal variables	Control		Parkinson		P-value
	Mean	Std. Deviation	Mean	Std. Deviation	
LEFT Cadence (step per min)	104.19	13.29	99.41	21.50	0.46
LEFT Single Support (%)	38.74	2.81	34.71	5.06	0.01*
LEFT Double Support (%)	24.78	4.81	30.26	10.43	0.07
LEFT Stride Length (meter)	1.26	0.12	1.00	0.28	0.00*
LEFT Walking Speed (meter per second)	1.10	0.18	0.83	0.31	0.01*
LEFT STANCE (%)	63.51	6.22	64.98	7.63	0.57
RIGHT Cadence (step per min)	104.13	14.16	99.75	22.07	0.52
RIGHT Single Support (%)	37.25	3.21	37.43	6.80	0.93
RIGHT Double Support (%)	23.35	3.51	28.72	7.49	0.02*
RIGHT Stride Length (meter)	1.27	0.12	0.97	0.29	0.00*
RIGHT Walking Speed (meter per second)	1.10	0.19	0.81	0.32	0.00*
RIGHT STANCE (%)	60.60	4.77	66.15	6.41	0.01*

Table 3: *Mean values of the peaks of the forces applied on the leg of the control and Parkinson groups*

Variable	**Control**		**Parkinson**		**P-value**
	Mean	**Std. Deviation**	**Mean**	**Std. Deviation**	
L_FMAX_ML	13.67	2.31	12.83	3.56	0.44
L_F progression	35.02	6.17	25.61	14.25	0.02*
L_F Breaking	29.11	8.65	24.41	11.36	0.21
L_FV_FZ1	112.74	9.26	107.13	10.35	0.129
L_FV_FZ2	84.92	12.72	88.80	10.95	0.381
L_FV_FZ3	114.99	10.07	100.25	6.87	0.00*
L-FORCE-TIME -INTEGRATED	65.33	10.22	61.26	7.65	0.23
R_FMAX_ ML	13.05	2.10	13.18	2.76	0.89
R_F progression	35.18	6.49	25.60	11.90	0.01*
R_F Breaking	30.11	6.52	23.93	13.07	0.11
R_FV_FZ1	113.59	8.97	108.71	15.74	0.298
R_FV_FZ2	85.25	12.83	89.78	11.62	0.322
R_FV_FZ3	114.15	9.80	101.67	6.74	0.00*
R_FORCE_TIME_INTEGRATED	65.31	10.33	61.92	6.81	0.31
DIS_ML	0.05	0.13	-0.04	0.15	0.12
DIS_AP	0.00	0.12	-0.02	0.16	0.78
DIS_V	0.02	0.05	0.00	0.06	0.23

L=*Left;* **FMAX**=*Force Maximum;* **FMIN**=*Force Minimum;* **ML**=*Medio-Lateral;* **AP**=*Anterior-Posterior;* **V**=*Vertical;* **DIS _ML**= *The discrepancy between left and right medio-lateral force;* **DIS_AP**=*The discrepancy between left and right anterior-posterior force;* **DIS_V**=*The discrepancy between left and right vertical force*

normal and the subjects with PD are shown in Table 2. As it can be seen from these results, there was no difference between left and right cadence of normal and those with PD ($p > 0.05$). The mean values of double support percentage of the subjects with PD were 28.72±7.49 and 30.26±10.43 in right and left sides, respectively, compared to 23.35±3.51 and 24.78±4.81 in normal subjects (the difference between right limb double support of normal and patients with PD was significant ($p = 0.02$). There were significant differences between walking speed in normal subjects and those with PD in both right and left lower limbs (p ranged from <0.001 to 0.01). Stride length of subjects with PD varied between 1±0.28 m and 0.97±0.29 compared to normal subjects which varied between 1.26±0.12 and 1.27±0.12 m ($p < 0.001$).

Table 3 provides the summary of the mean values of

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the peaks of the force applied on the legs in both group of participants. The mean values of breaking force of the left side were 29.11±8.66N/BW and 24.41±11.36 N/BW in normal and patients with PD, respectively (p = 0.21). There was no difference between the breaking force applied on the right and left sides in normal and those with PD. The progression force of subjects with PD differs significantly from that of normal subjects in both right and left sides (p < 0.02).

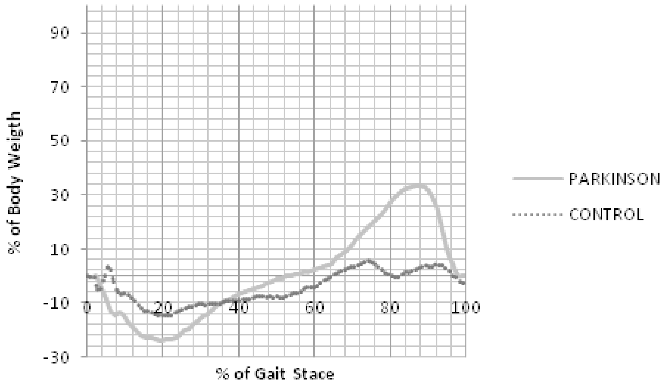

Figure 2: *Illustration of horizontal ground reaction force of a Parkinson and a Control subject. Positive values represent propulsion. Negative values represent braking*

The peak of the vertical force applied on the leg was the other parameter evaluated in this study. Based on this parameter, the mean value of the first peak of vertical force applied on the leg in subjects with PD was slightly less than that of normal subjects (p > 0.12). However, the second peak of vertical force decreased significantly in this group of subjects on both sides (p <0.001).

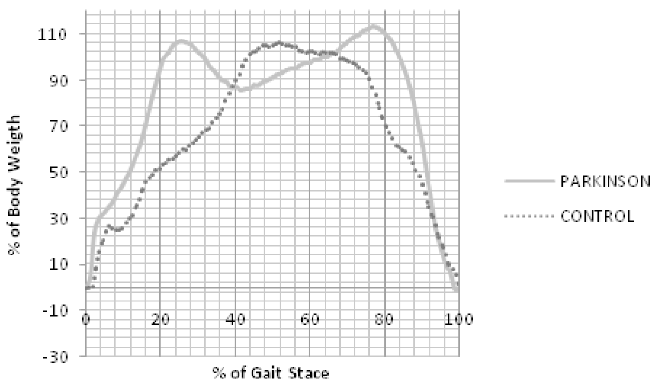

Figure 3: *Illustration of vertical ground reaction force of a Parkinson and a normal subject*

The difference between mediolateral forces of both groups was not statistically significant. Force time integral (FTI) of the vertical force was also studied. Based on this parameter, the FTI of normal and those with PD was nearly the same. There was no difference between the peaks of the forces applied on the right and left legs in both group of participants (p > 0.05). Figures 2, 3 and 4 show the patterns of the forces applied on the leg in a normal and a Parkinson subject.

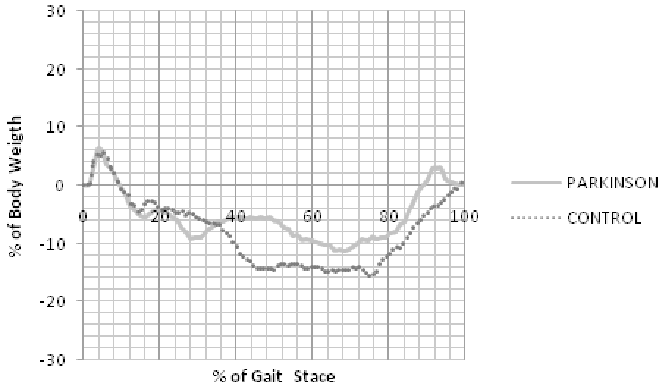

Figure 4: *Illustration of mediolateral ground reaction force of a Parkinson and a normal subject*

Discussion

Parkinson disease (PD) is one of the important neurological disorders that influence the ability of subject's standing and walking. Based on results of various studies, it is possible to conclude that subjects with PD have decreased in range of motion of lower limb joints (Morris et al., 1999), instability during standing (Wiese, 2006) and irregularities in EMG activities of muscles (Nieuwboer et al., 2004). However, there was no study that has investigated forces applied on the leg in this group of subjects. In addition, the asymmetry of the force applied on the both sides has not been reported in patients with PD. Therefore, the aim of this study was to evaluate the force applied on the leg, and the symmetry of applied force.

As can be seen from the results of this research presented in Table 2, the walking speed of patient with was significantly different from that of normal due to reduce stride length. This agrees with the findings of Roiz et al. (2010). They observed that a decrease in walking speed was due to decreased number of cadence and stride length (Morris et al., 1994). The main reason for decreased stride length is reduced range of motion of ankle, knee and hip joints as they may need to decrease their walking speed and increase their double support limb percent to improve dynamic stability. Selecting a slower speed and increasing double limb support represent a way in which patients with PD decrease the magnitude of destabilizing forces, particularly by reducing the perturbation to the centre of mass at push-off (Morris et al., 1999). One of the parameters, which represent dynamic stability, is walking speed. It has been shown that subjects with neuromuscular disorders decrease their walking speed to control their stability.

The results also showed that patient with PD walked with a different proportion of the gait cycle. They increased double limb support during walking. Usually people increase double limb support time to compensate for fear of falling (Maki, 1997) or postural instability (Winter, 1991; Winter et al., 1990), both which are common in advanced PD (Morris et al., 1995). Extending the proportion of the gait cycle in double limb support increases the time available to re-establish stabilization, thereby minimizing the demands on an inadequate postural control system.

The study also showed that the mean values of propulsive component of anteroposterior force decreased significantly in PD group of subjects. The main reason may be related to performance of ankle joints plantar flexor which decreased in this group of subjects (Sofuwa et al., 2005). The second peak of vertical ground reaction force decreased significantly in PD group of subjects. Decrease in ankle joint plantar flexor and walking speed were the main reason in this regard. However, it should be noted that the pattern of vertical force applied on the leg differ significantly in patients with PD. In normal subjects, there is a valley in the graph of vertical force due to extension of knee joint in mid stance. There was a slight increase in mean values of force applied on the leg in midstance (second force valley in PD), which may be due to flexed posture of the leg in this group of subjects.

Symmetry of force between right and left sides has been evaluated in some neuromuscular disorders such as multiple sclerosis by use of asymmetry index. It has been shown that there are some asymmetry regarding the force applied on the leg in patients with multiple sclerosis (Benedetti et al., 1999). There was no difference between the forces of the right and left sides in both normal and patients with PD. It means that the effect of the disease in this group of subjects was the same in both right and left sides.

There are some limitations which should be acknowledged in this study. The main limitation was that only 14 subjects were selected in this study. Moreover, in this study, the subjects with severely of II and III based on Hohen and Yahr (1998) scale were recruited. Therefore it is recommended that in the future studies, subjects with various severities should be selected.

Conclusions

These subjects have to decrease their walking speed and increase their double limb support percent to improve dynamic stability and decrease the magnitude of destabilizing forces. The mean values of propulsive component of anteroposterior force and the second peak of vertical ground reaction force decreased significantly due to performance of ankle joints plantar flexor which decreased in this group of subjects.

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Conflict of interest

No conflict of interest exists.

Authors' Contribution

Both authors contributed equally in the study design and performance.

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