Journal of Basic and Clinical
PATHOPHYSIOLOGY
Volume 2. Number 2. 2014

Correlation Between Functional Balance and Mobility Tests and Postural Sway Measures in Dual Task Paradigm in Parkinson's Disease (a Pilot Study)

Ehsan Pourghayoomi[1], Feraidoon Negahdar[2], Gholamali Shahidi[3], Afsoun Hassani Mehraban[1], Ismaeil Ebrahimi[4], Ghorban Taghizadeh*[1], Mina Mirshoja[1], Mehrdad Saeidi Boroujeni[1]

1. *Department of Occupational Therapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran.*
2. *Lecturer of Anatomy Department, Iran University of Medical Sciences, Tehran, Iran.*
3. *Assistant Professor of Neurology, Division of Movement Disorder, Department of Neurology, Rasool-e Akram Hospital, Iran University of Medical Sciencnes, Tehran, Iran.*
4. *Professor of Physical Therapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran.*

Article info
Received: 26 Jan 2014
Revised: 16 Feb 2014
Accepted: 24 Feb 2014

A B S T R A C T

Objective: The present study was aimed to correlate the clinical tests with the laboratory measures under dual task conditions in Parkinson's disease (PD).

Materials and Methods: Eleven people with idiopathic PD (Modified Hoehn and Yahr scores 1-3) were selected by simple non-probability sampling. Center of pressure (COP) data obtained by force platform was used to calculate mean total velocity, standard deviation (SD) of amplitude along anterior-posterior (A.P) and medial-lateral (M.L) directions, path length and total phase plane in four levels of postural difficulty (quiet standing on rigid and foam surface with open and closed eyes) and two levels of cognitive difficulty (with and without cognitive task). Functional Reach (FR), Timed UP and Go (TUG), Berg Balance Scale (BBS), and gait speed tests were used for clinical assessment.

Results: There was no significant correlation between FR and TUG test and any of COP parameters in different levels of postural and cognitive difficulty. Among different COP parameters, SD of amplitude (A.P) in standing on rigid surface with closed eyes without cognitive task and in standing on foam with closed eyes and cognitive task showed moderate to high correlation with BBS. Also significant correlation was seen between the SD of amplitude (A.P) in standing on foam with open eyes without cognitive task and gait speed test.

Conclusion: No correlation was seen between Laboratory and clinical measures, indicating that they might evaluate different dimensions of balance control in PD.

Key Words:
Parkinson's disease
Clinical tests
Force plate parameters

1. Introduction

Parkinson's disease (PD) is a chronic and progressive neurodegenerative disease caused by the destruction of dopaminergic neurons in the basal ganglia (1) and is the second, most common neurodegenerative disorder after Alzheimer's disease (2). Impaired postural control is one of the most common symptoms (3), probably leading to falls in 25 to 50 percent of the patients with PD (4), in turn lead to increased dependence

***Corresponding Author:** *Ghorban Taghizadeh*
Department of Occupational Therapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran.
Email: gh_taghizade@yahoo.com

in activities of daily living (5) as well as imposing large costs to the families of the patients (6).

Balance maintenance, as a part of postural control and a coordinated action of central nervous system, is defined as a control of connections between sensory and motor systems to regulate the relationship between the center of body mass and the base of support through appropriate muscle responses. The risk of falling increases if this control is not done properly (7). Because of sensory impairments such as proprioceptive impairments and motor dysfunctions including inability to predict the movement amplitude, poor timing and weakness in reactive responses, sensation and movement interaction is impaired in patients with PD (8).Therefore, use of appropriate balance evaluation methods in patients with PD plays an important role in understanding how the postural control system works, in clinical diagnosis, in evaluation of treatment's results and in areas with the risk of falling for these patients (9).

Clinical and laboratory evaluation methods have been proposed to assess the balance. Clinical evaluations have different guidelines and methods and may be time limited, functional and/or observational tests (10). Among these assessments, Functional Reach (FR), Timed Up and GO (TUG), Berg Balance Scale (BBS) and Gait Speed are the most commonly used clinical evaluations. Because of the convenience and low cost, most of these tests are widely used in clinics (7); However, few studies have been carried out on the relationship of these tests with laboratory tests. Also, these tests have not been reported as appropriate to measure the exact mechanism of balance (11).In many studies, force plate is used for laboratory evaluation of balance in patients with PD (12-13). Balance assessment using force plate is based on determination of the parameters associated with center of pressure (COP) displacements which is the point of application of vertical forces acting on the base of support (14). COP parameters have been reported as sensitive laboratory criteria for measuring the balance under different conditions in various diseases (15-18).

Studies of the correlation between clinical and laboratory evaluations are important to assess the suitability of a test and to increase the knowledge of postural control (19).Correlation between COP fluctuations and functional balance and mobility tests in stroke patients has been evaluated in many studies. In these studies, COP fluctuations have been investigated in different task such as quiet standing, movement and bending and reaching, and contradictory results (weak to strong correlation) have been reported (19-28). Also, other studies on correlation between functional balance and mobility tests and postural sway parameters were reported in elderly. Gil et al., reported weak correlation (0.2-0.28) between COP parameters in one-leg standing and one-leg standing functional balance test and functional agility/dynamic balance test in older people (29). Desai et al., studied the correlation between BBS, TUG, gait speed and Six Minutes Walking Test (6MWT) and COP sway in postural task on rigid and foam surface (quiet standing with open and closed eyes, standing with a regular rotation of head along with a visual target, standing witha regular movement of the elbow to lift and lower an object, standing with regular rotation of the trunk to 45 degrees and standing with a regular trunk bending and flattening to 30 degrees) in elderly with and without a history of falling and indicated weak correlation between COP sway parameters and scores of the functional balance and mobility tests (30). Sabchuk et al., studied the correlation between COP fluctuations (in 5 conditions: feet apart with open and closed eyes, feet together with open and closed eyes, semi tandem position with open eyes) and BBS, TUG, Performance Oriented Mobility Assessment (POMA) and FR and reported high correlation between COP fluctuations and BBS and TUG (7). In none of the previous studies, the correlation between COP fluctuations and functional balance and mobility tests has been investigated in patients with PD.

Simultaneously performing a cognitive and postural control tasks is defined as a dual task (31-32).Correlation between cognitive impairments and falling has been reported in older subjects, patients with PD and other neurological diseases (33-37).Performing activities such as walking with the dual tasks may increase the risk of falling in these individuals (38). Thus, it can be said that the dual tasks are harder than single tasks and are challenging for these patients. Although the effect of dual task on motor functions of patients with PD has been investigated in the previous studies (37-39), but

the correlation between COP sway parameters in dual task condition (postural with cognitive task) and functional balance and mobility tests has not been studied in these patients. Therefore, given the importance of this issue, the aim of this study was aimed at investigating the correlation between COP fluctuations in dual task condition and functional balance and mobility tests including FR, TUG, BBS and gait speed tests in patients with PD.

2. Materials and Methods

In this study, 11 patients with idiopathic PD (6 male and 5 female, 5 patients with left more affected side and 6 with right more affected side) were selected from neurology and rehabilitation clinics in Tehran by non-probability simple sampling method. Their mean age was 54.27±12.61 years (range: 31-72); their mean post-diagnosis time was 7.79±4.97 years (range: 1.5-16); their mean height was 165.1±11.49 cm (range: 145-185); and their mean weight was 71.18±20.74 kg (range: 42-120). According to the Modified Hoehn and Yahr scale, one patient was at the level 1, one patient was at the level 1.5, five patients were at the level 2 and four patients were at the level 3. The inclusion criteria were: 1) having PD diagnosed by a neurologist (with 1-3 level of the disease severity according to the Modified Hoehn and Yahr (1967)), 2) having appropriate level of cognitive function based on Mini Mental Status Examination (MMSE) (acquired score≥21), 3) not having non-soluble visual impairments with glasses based on patient report, 4) having an ability to walk at least 10 meters independently without any assistive device, 5)having an ability to stand on foam with closed eyes and simultaneous cognitive task for two minutes, 6) not having any history of orthopedic disease, diabetes, addiction, and neurologic disease other than PD. Patients were excluded if they could not have cooperation in testing. The project was approved by the Ethics Committee at Iran University of Medical Sciences and all participants were given written consent to take part in the study.

FR, TUG, BBS, and gait speed tests were used for evaluation of functional balance and mobility and force plate was used for laboratory measuring of COP fluctuations. All tests were conducted in a random order in one day for each participant.

To perform FR test, the participants were required to stand with their less affected side near a wall and the examiner marked on the wall horizontally and parallel to the ground at the level of acromion of less affective side. Then, patients elevated the less affective upper limb to the shoulder height (90◦ of flexion) and reached forward (with extended position of elbow) along the marked line with maximum effort and without lifting their feet or stepping. Then, the examiner measured the traveled distance using the ruler. This test was performed trice and the mean score was considered as the FR score. This test has an excellent test-retest reliability (Interclass Correlation Coefficient (ICC)=0.94) (40-41).

For the TUG test, subjects were asked to rise from a chair, walk a distance of 3 meters and then come back and sit on the chair. The participants must walk with maximum speed and safety. Seat height for this test was determined based on the length of each patient's leg so that when the patient sat on a chair, knees bent 90 degrees and feet were on the floor. The experimenter recorded the time of completing this test in seconds using the timer. High within session reliability in drug off- and on-phase (r=0.8-0.98 and 0.73-0.99, respectively) and very high inter-rater reliability (ICC=0.87-0.99) has been reported for this test in patients with PD (42). The test was repeated three times and the average was considered as the main data.

BBS test consists of 14 items that are: 1) rising from sitting position on the chair, 2) quiet standing without support, 3) quiet sitting on a chair without support, 4) sitting on a chair from quiet standing, 5) transfer, 6) quiet standing with closed eyes, 7) quiet standing with feet together, 8) reaching forward in standing position, 9) picking up objects from the floor, 10) turning to look behind, 11) turning 360°, 12) placing alternate foot on as tool, 13) standing with one foot in front, 14) standing on one leg. A chronometer, a thirty-centimeter ruler, a stool with a height of 20 cm, a chair with a backrest and 42 cm height and a seat with 42 cm height and backrest and without handle were used for assessment in this test. Each item is scored from zero to four and the total score of this test is 56 (43). Very high inter-rater and test-retest reliability (ICC=0.93 and 0.95, respectively) has been reported for this test in elderly (44).

To perform Gait Speed Test, a walkway of 9 meters length was marked in a straight line. The first and last 2 meters were considered as acceleration and deceleration zone and the middle 5 meters zone was used to measure gait speed. Subjects were asked to walk a distance of 9 meters with a maximum speed when they heard the command "Ready, go". The timer was activated at the end of the first 2 meters and it was stopped at the end of the middle 5 meters. The speed was calculated by dividing the traveled distance (5 meters) by the time (in seconds). Each participant was tested three times and the average was taken as the final data. Excellent test-retest reliability (ICC=0.88-0.97) has been reported for this test (45).

Kistler Force Platform (model: 2812A; version: 5.3.1.0; sampling frequency: 100 HZ) was used for laboratory recording of COP sway. This tool has a non-moving force plate with piezoelectric sensors and software which has been developed to measure pressure, force, torque and acceleration. Four levels of postural difficulty (quiet standing on rigid surface and foam (dimensions: 60x50x10) with open and closed eyes) and two levels of cognitive difficulty (with and without cognitive task) were considered. The subjects were asked to stand on the force plate comfortably with bare feet and arms along the body so that the feet were apart as much as 4 fingers and the tip of the thumb and heel of the foot were be aligned in parallel. In the condition of standing with open eyes, subjects must look directly to a page at the distance of 5 meters. While in the condition of standing with closed eyes, their eyes were closed using a black cloth blind. Postural data collection was done twice for 70 seconds in both single and dual task conditions. If there was additional movement in the trunk, head or upper extremity in order to maintaining the balance, test was done again. Wechsler Intelligence Scale was used to perform cognitive tasks. “Working memory capacity” of subjects was determined using digits backward test of this scale. Participants were asked to listen carefully to a string of random numbers, which was repeated twice at a constant volume and rate. before the postural data collection and at the end of each dual task trial participants were asked to repeat the heard digits backwardly (46).

The order of experimental conditions was randomized for each subject. In order to maintain patients’ safety at all stages of this study, a person stood behind them. All experimental and laboratory tests were done in the same day and in drug on-phase (an hour after taking the medication) (5, 47).

2.1. Data Analysis

In order to investigate the postural function in each condition, COP sway parameters including the mean total velocity, standard deviation (SD) of amplitude along anterior-posterior (A.P) and medial-lateral (M.L) directions, path length and total phase plane were calculated and the mean of two trials for each task was used for statistical analysis of each parameter. former studies have indicated that the COP parameters are sensitive and appropriate instrument for measuring postural performance (48).

2.2. Statistical Analysis

The Shapiro-Wilk (W) test was used to determine normal distribution of data. All postural sway parameters and the scores of all functional balance and mobility tests were normally distributed. Pearson product moment correlation and coefficient of determination (R^2) was used to investigate the correlation between functional balance and mobility tests and COP sway parameters. Also, Scatter plot of Pearson product moment correlation was determined for significant correlations. Munro 's scale was used to determine the strength of correlation in which its values of 0-0.25, 0.26-0.49, 0.5-0.69, 0.7-0.89 and 0.9-1 shows little/no, low, moderate, high, very high correlation, respectively (49). P value <0.05 was considered statistically significant.

3. Results

The mean±SD of the scores of the functional balance and mobility tests was as follows: FR: 12.87±5.18 (cm) in the range of 6.2-23.5; TUG: 6.62±2.04 (s) in the range of 4-11.77; BBS: 45.82±6.37 in the range of 31-53; Gait Speed: 3.01±0.46 (m/s) in the range of 2-3.79. Table 1 shows the mean (SD) of COP parameters in different conditions of postural and cognitive task. There was no significant correlation between age and each of the functional balance and mobility tests including FR (r=0.001,

p=0.99), TUG (r=0.314, p=0.3), BBS (r=0.486, p=0.13) and gait speed (r=0.067, p=0.85). Also, there was no significant correlation between age and any of COP parameters in different levels of postural and cognitive difficulty.

3.1. Correlation between Functional Balance and Mobility Tests and COP Parameters in Single Postural Task Condition

There was no significant correlation between FR and TUG test and any of COP parameters (SD of amplitude along A.P and M.L directions, mean velocity, path length and total phase plane) in different levels of postural difficulty (standing on rigid surface and foam with open and closed eyes) (Table 2).

The same results was obtained for the correlation between BBS and COP parameters indifferent conditions of single postural task with the exception of the SD of amplitude along AP direction in standing on rigid surface with closed eyes (Table 2)which indicate significant moderate correlation (r= -0.633, p=0.037)with BBS (Fig. 1).

Table 1. Mean (SD) of COP Parameters in Different Conditions of Postural and Cognitive Difficulty for PD in Quiet Standing

Levels of Cognitive Difficulty	Levels of Postural Difficulty			
	Rigid surface		Foam surface	
	Open Eyes	Closed Eyes	Open Eyes	Closed Eyes
Without Cognitive Task				
SD of amplitude (A.P)	0.06 (0.01)	0.06 (0.03)	0.10 (0.02)	0.13 (0.05)
SD of amplitude (M.L)	0.04 (0.01)	0.04 (0.01)	0.09 (0.02)	0.10 (0.03)
Mean velocity	0.18 (0.04)	0.20 (0.03)	0.23 (0.05)	0.25 (0.06)
Path length	12.5 (2.66)	13.90 (2.08)	15.98 (3.50)	17.30 (4.19)
Total phase plane	0.42 (0.08)	0.46 (0.07)	0.55 (0.12)	0.60 (0.14)
With Cognitive Task				
SD of amplitude (A.P)	0.06 (0.01)	0.07 (0.03)	0.09 (0.02)	0.12 (0.04)
SD of amplitude (M.L)	0.05 (0.03)	0.05 (0.02)	0.09 (0.02)	0.10 (0.02)
Mean velocity	0.21 (0.07)	0.23 (0.09)	0.21 (0.04)	0.25 (0.06)
Path length	14.42 (4.64)	15.92 (6.16)	15.09 (3.03)	17.50 (4.05)
Total phase plane	0.45 (0.04)	0.53 (0.21)	0.56 (0.18)	0.68 (0.28)

* Unit of SD of amplitude and path length is cm. Mean velocity is cm/s. Total phase plane is an Arbitrary Unit.

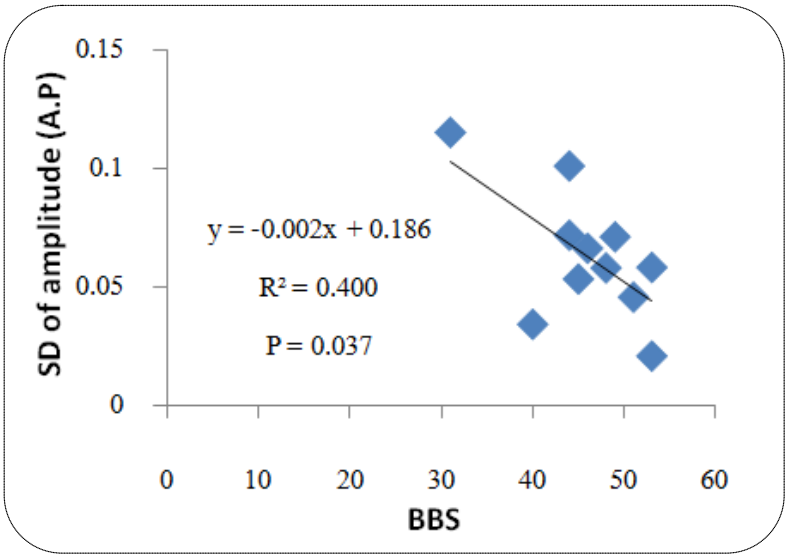

Figure 1. Regression line plotted between Berg Balance Scale (BBS) and SD of amplitude (A.P) parameter in standing on rigid surface with closed eyes.

Table 2. Correlation Coefficient (R2) between the Functional Balance and Mobility Tests and COP Parameters in Different Conditions of Postural Difficulty without Cognitive Task for PD in Quiet Standing

Without Cognitive Task		Levels of Postural Difficulty			
		Rigid surface		Foam surface	
		Open Eyes	Closed Eyes	Open Eyes	Closed Eyes
FR with	SD of amplitude (A.P)	0.139 (0.019)	-0.368 (0.135)	-0.037 (0.001)	-0.542 (0.293)
	SD of amplitude(M.L)	-0.197 (0.039)	-0.172 (0.029)	-0.182 (0.033)	-0.225 (0.051)
	Mean velocity	-0.006 (0.000)	-0.071 (0.005)	-0.162 (0.026)	-0.115 (0.013)
	Path length	-0.006 (0.000)	-0.071 (0.005)	-0.162 (0.026)	-0.115 (0.013)
	Total phase plane	-0.083 (0.006)	-0.131 (0.017)	-0.267 (0.071)	-0.190 (0.036)
TUG with	SD of amplitude (A.P)	0.329 (0.108)	0.167 (0.027)	0.462 (0.213)	0.260 (0.067)
	SD of amplitude (M.L)	0.190 (0.036)	0.172 (0.029)	-0.037 (0.001)	-0.146 (0.021)
	Mean velocity	0.246 (0.060)	0.180 (0.032)	0.452 (0.204)	0.241 (0.058)
	Path length	0.246 (0.060)	0.180 (0.032)	0.452 (0.204)	0.241 (0.058)
	Total phase plane	0.254 (0.064)	0.178 (0.031)	0.499 (0.249)	0.284 (0.080)
BBS with	SD of amplitude (A.P)	-0.013 (0.000)	**-0.633** (0.400)**	0.149 (0.022)	-0.599 (0.358)
	SD of amplitude (M.L)	-0.136 (0.018)	-0.067 (0.004)	-0.046 (0.002)	-0.358 (0.128)
	Mean velocity	-0.091 (0.008)	0.161 (0.025)	-0.454 (0.206)	-0.116 (0.013)
	Path length	-0.091 (0.008)	0.160 (0.025)	-0.454 (0.206)	-0.116 (0.013)
	Total phase plane	-0.240 (0.057)	0.048 (0.002)	-0.589 (0.346)	-0.204 (0.041)
Gait speed	SD of amplitude (A.P)	-0.427 (0.182)	-0.165 (0.027)	**-0.643* (0.413)**	-0.482 (0.232)
	SD of amplitude (M.L)	-0.212 (0.045)	-0.058 (0.003)	-0.145 (0.021)	-0.262 (0.069)
	Mean velocity	0.054 (0.002)	-0.201 (0.040)	0.006 (0.000)	-0.202 (0.040)
	Path length	0.054 (0.002)	-0.200 (0.040)	0.006 (0.000)	-0.202 (0.040)
	Total phase plane	0.047 (0.002)	-0.214 (0.045)	-0.076 (0.005)	-0.270 (0.072)

*P<0.05, **P<0.01. Unit of SD of amplitude and path length is cm. Mean velocity is cm/s. Total phase plane is an Arbitrary Unit.

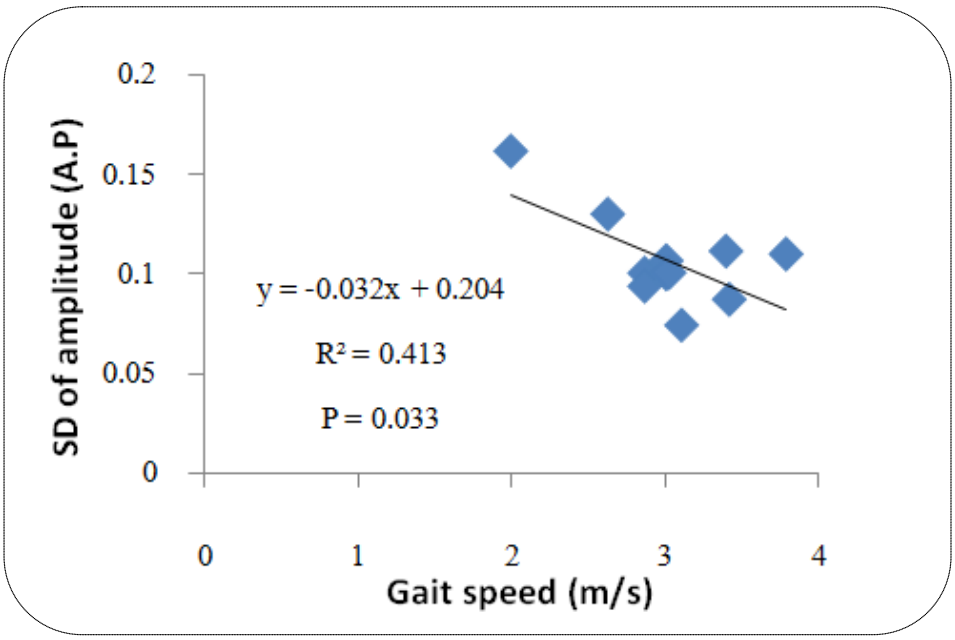

Figure 2. Regression line plotted between Gait Speed and SD of amplitude (A.P) parameter in standing on foam with open eyes.

No significant correlation was observed between gait speed test and any of COP parameters in different conditions of single postural task with the exception of the SD of amplitude along AP direction in standing on foam with open eyes (Table 2) which indicate significant moderate correlation (r=-0.643, p=0.033) with gait speed test (Fig. 2).

3.2. Correlation between Functional Balance and Mobility Tests and COP Parameters in Dual Task Condition

No significant correlation was found between FR, TUG, and gait speed test and any of COP parameters (SD of amplitude along A.P and M.L directions, mean velocity, path length and total phase plane) in different difficulty levels of Postural (standing on rigid surface and foam with open and closed eyes) with cognitive task (Table 3).

No significant correlation was observed between BBS and any of COP parameters in different conditions of postural with cognitive task with the exception of the SD of amplitude along AP direction in standing on foam with closed eyes (Table 3) which indicate significant high correlation(r= -0.828, p= 0.002) with BBS (Fig 3).

Table 3. Correlation Coefficient (R2) between the Functional Balance and Mobility Tests and COP Parameters in Different Conditions of Postural Difficulty with Cognitive Task for PD in Quiet Standing

With Cognitive Task		Levels of Postural Difficulty			
		Rigid surface		Foam surface	
		Open Eyes	Closed Eyes	Open Eyes	Closed Eyes
FR with	SD of amplitude (A.P)	0.291 (0.084)	-0.226 (0.051)	-0.302 (0.091)	-0.422 (0.178)
	SD of amplitude(M.L)	0.010 (0.000)	-0.150 (0.022)	-0.496 (0.246)	0.012 (0.000)
	Mean velocity	-0.157 (0.024)	-0.120 (0.014)	-0.113 (0.012)	-0.141 (0.019)
	Path length	-0.157 (0.024)	-0.120 (0.014)	-0.113 (0.012)	-0.141 (0.019)
	Total phase plane	-0.314 (0.098)	-0.135 (0.018)	-0.171 (0.029)	-0.134 (0.018)
TUG with	SD of amplitude (A.P)	-0.116 (0.013)	-0.296 (0.087)	0.443 (0.196)	0.447 (0.199)
	SD of amplitude(M.L)	-0.260 (0.068)	-0.119 (0.014)	0.307 (0.094)	0.219 (0.048)
	Mean velocity	0.170 (0.029)	0.210 (0.044)	0.113 (0.012)	0.410 (0.168)
	Path length	0.170 (0.029)	0.210 (0.044)	0.113 (0.012)	0.410 (0.168)
	Total phase plane	0.135 (0.018)	0.196 (0.038)	0.224 (0.050)	0.361 (0.130)
BBS with	SD of amplitude (A.P)	-0.208 (0.043)	-0.369 (0.136)	-0.237 (0.056)	**-0.828** ** **(0.685)**
	SD of amplitude(M.L)	-0.082 (0.007)	-0.245 (0.060)	-0.307 (0.094)	-0.363 (0.131)
	Mean velocity	-0.239 (0.057)	-0.300 (0.090)	-0.189 (0.035)	-0.240 (0.057)
	Path length	-0.239 (0.057)	-0.300 (0.090)	-0.188 (0.035)	-0.240 (0.057)
	Total phase plane	-0.028 (0.000)	-0.338 (0.114)	-0.435 (0.189)	-0.426 (0.181)
Gait speed	SD of amplitude (A.P)	0.254 (0.064)	0.104 (0.010)	-0.250 (0.062)	-0.179 (0.032)
	SD of amplitude(M.L)	0.230 (0.053)	0.132 (0.017)	-0.322 (0.104)	-0.102 (0.010)
	Mean velocity	0.178 (0.031)	0.194 (0.037)	0.069 (0.004)	-0.205 (0.042)
	Path length	0.178 (0.031)	0.194 (0.037)	0.068 (0.004)	-0.205 (0.042)
	Total phase plane	-0.352 (0.124)	0.192 (0.036)	0.239 (0.057)	-0.104 (0.010)

*P<0.05, **P<0.01.
Unit of SD of amplitude and path length is cm. Mean velocity is cm/s. Total phase plane is an Arbitrary Unit.

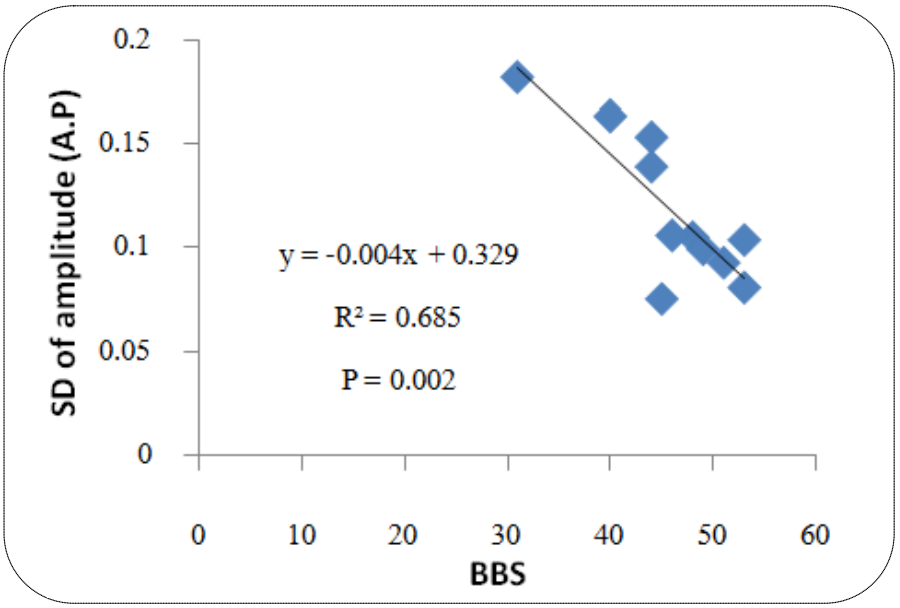

Figure 3. Regression line plotted between Berg Balance Scale (BBS) and SD of amplitude (A.P) parameter in standing on foam with closed eyes and cognitive task.

4. Discussion

The aim of the current study was to determine the relationship between common functional balance and mobility tests and a number of COP parameters recorded by a force platform during four levels of postural difficulty (standing on rigid surface and foam with open and closed eyes) and two levels of cognitive difficulty (with and without cognitive task) in PD.

A significant negative and moderate relationship was shown between total score of BBS and SD of COP-amplitude along AP direction in standing on rigid surface with closed eyes without cognitive task. Also, the total score of BBS was significantly and highly correlated to SD of COP-amplitude along AP direction in standing on foam with closed eyes and cognitive task. This result indicates that those with greater sway measured by force platform had a lower functional balance and vice versa. This finding can be explained by the fact that the Parkinsonian subjects with lower postural control may have a greater tendency to increase the stiffness of their postural system and limit their central pressure sway during maintenance of balance in quiet stance (24, 50-51). But this level of correlation indicates that only about 40% and 69% of the total variance in scores of BBS are explained by the postural sway parameter and so other factors may have a considerable contribution to their estimation. This result is in line with the reports by Corriveau et al (23), who indicated moderate and significant correlation between COP-amplitude along AP direction and total score of BBS in stroke subjects. The gait speed test, as a mobility test, indicated a negative and moderate relationship with the SD of COP-amplitude along AP direction in standing on foam with open eyes without cognitive task. The current result demonstrated that when the postural sway of patients with PD increased in quiet standing, the gait speed decreased. Such relationship between the gait speed test and the parameters of postural sway in people with PD had not been previously documented in the literature.

The result of the present study demonstrated that the FR and TUG tests were not correlated with postural sway parameters during quiet standing in any levels of postural and cognitive difficulty. It can be suggested that increasing the levels of postural and cognitive difficulty did not affect this relationship. Also, no association was found between BBS and gait speed tests and the mean velocity, path length, SD of amplitude along ML direction and total phase plane variables in all conditions. This result is consistent with previous findings, even those using different balance and mobility methods, that have also seen weak, moderate or even no

correlation between the postural sway measures and clinical tests in healthy, elderly and stroke subjects (19, 24, 27, 29-30, 52-54). Also this finding indicates that properties of the task and the environment play an important role in evaluation of postural control (19-20, 55-56). This finding may show that the two protocols of balance evaluation (COP sway and clinical tests) capture information about different aspects of balance. The amount of COP sway seems to reflect more sensorimotor, biomechanical and neuromuscular deficits than performance-based ability (27, 29-30, 54). However, the functional balance evaluations are large scale tools and can never be completely associated to a measure of functional capacity, because other factors also contribute to performance decrease (54). The limitation of this study is the convenience sampling and small sample size. Further study with a much larger sample is recommended to eliminate a statistical negative effect.

In conclusion, our study was the first research at finding a correlation between clinical and laboratory measures of balance in patients with PD. In these subjects, clinical and instrumental measures of balance were not relevant in most of the postural sway parameters. Thus, COP and clinical measures are seemed to assess the different aspects of balance; therefore we suggest that combining clinical and laboratory evaluations, whenever possible, would increase comprehension of balance impairments and disabilities in PD.

Acknowledgments

The study was supported by Iran University of Medical Sciences, Tehran, Iran.

References

1. Woo Y, Lee J, Hwang S. Cheol PH. Use of an Adaptive Neuro-fuzzy Inference System to Obtain the Correspondence among Balance, Gait, and Depression for Parkinson's Disease. Journal of the Korean Physical Society 2013; 62(6): 959-965.

2. Ma C, Su L, juan Xie J, Long x, Wu P, Gu L. The prevalence and incidence of Parkinson's disease in China: a systematic review and meta-analysis. Journal of Neural Transmission 2013.

3. Margaret KY and Pang MY.Fear of falling is independently associated with recurrent alls in patients with Parkinson's disease: a 1-year prospective study. Journal of Neurology 2009; 256: 1689-1695.

4. Plotnik M, Giladi N, Dagan Y, Hausdorff J. Postural Instability in Patients with Parkinson's Disease. Central Nervous System Drugs 2013; 27(2): 97-112.

5. Langley FA, Macintosh SFH. Functional balance assessment of older community dwelling adults: A systematic review of the literature. The Internet Journal of Allied Health Science and Practice 2007; 5(4).

6. Fletcher E, Goodwin VA, Richards SH, Campbell JL, Taylor RS. An exercise intervention to prevent falls in Parkinson's: an economic evaluation. BMC Health Services Research 2012; 426(12).

7. Sabchuk RAC, Bento PCB, Rodacki ALF. Comparison between field balance tests and force platform. Revista Brasileira de Medicina do Esporte 2012; 18 (6): 404-408.

8. Conradsson D, Löfgren N, Ståhle A, Hagströmer M, Franzén E. A novel conceptual framework for balance training in Parkinson's disease-study protocol for a randomised controlled trial. Bio Medical Central Neurology 2012; 111(12).

9. Browne J and O'Hare NJ. A Review of the Different Methods for Assessing Standing Balance. Physiotherapy 2001; 87(9): 489-495.

10. Cowley A, Kerr K. A Review of Clinical Balance Tools for Use With Elderly Populations.Critical Reviews in Physical and Rehabilitation Medicine 2003; 15(34): 10-40.

11. Benatrua I, Vaugoyeaub M and Azulay JP. Postural disorders in Parkinson's disease. Clinical Neurophysiology 2008; 38: 459-465.

12. McVey MA, Stylianou AP, Luchies CW, Lyons KE, Pahwa R, Jernigan S, et al. Early biomechanical markers of postural instability in Parkinson's disease. Gait & Posture, 2009; 30: 538-542.

13. Qiu F, Cole MH, Davids KW, Hennig EM, Silburn PA, Netscher H, et al. Effects of textured insoles on balance in people with Parkinson's disease. PLOS ONE 2013; 8(12).

14. Nakazato K, Scheiber P, Muller E. Comparison between the force application point determined by portable force plate system and the center of pressure determined by pressure insole system during alpine skiing. Sport England 2013; 16:297-307.

15. Chern JS, Lo CY, Wu CY, Chen CL, Yang S, Tang FT. Dynamic postural control during trunk bending and reaching in healthy adults and stroke patients. American Journal of Physical Medicine & Rehabilitation 2010; 89:186-197.

16. de Haart M, Geurts AC, Huidekoper SC, Fasotti L, van Limbeek J. Recovery of Standing Balance in Postacute Stroke Patients: A Rehabilitation Cohort Study Archives of Physical Medicine and Rehabilitation 2004; 85: 886-895.

17. Mancini M, Salarian A, Carlson-Kuhta P, Zampieri C, King L, Chiari L, et al. ISway: a sensitive, valid and reliable measure of postural control. Journal of NeuroEngineering and Rehabilitation 2012; 59(9).

18. Nejc S , Jernej R, Loefler S, Kern H.Sensitivity of body sway parameters during quiet standing to manipulation of support surface size. Journal of Sports Science and Medicine 2010; 9: 431-438.

19. Frykberg GE, Lindmark B, Lanshammar H, Borg J.Correlation Between Clinical Assessment and Forceplate Measurment of Postural Control After Stroke. Journal of Rehabilitation Medicine 2007; 39: 448-453.

20. Binesh M, Mehraban AH, Amouzadeh Khalili M, Ghomashchi H, Hamedi D, Taghizadeh Gh. Relationship between functional balance tests and postural sway parameters in bending and picking up the object on the floor task in the chronic hemiparetic patients. Koomesh 2013; 14 (4): 455-465.

21. Binesh M, Taghizade Gh, Mehraban AH, Amouzadeh Khalili M, Hamedi D, Ghomashchi H. Relationship between symmetry index and postural sway parameters in dynamic task and functional balance tests in right and left hemiparesis patients (pilot study). Journal of Resarch in Rehabilitation Science 2012; 8(5).

22. Chern JS, Yang SW, Wu CY. Whole-body reaching as a measure of dynamic balance in patients with stroke. American Journal of Physical Medicine & Rehabilitation 2006; 85: 201-208.

23. Corriveau H, Hébert R, Raîche M, Prince F. Evaluation of Postural Stability in the Elderly With Stroke. Archives of Physical Medicine and Rehabilitation 2004; 85: 1095-101.

24. Fishman MN, Colby LA, Sachs LA, Nichols DS. Comparison of Upper-Extremity Balance Tasks and Force Platform Testing in Persons With Hemiparesis.Physical Therapy 1997; 77: 1052-1062.

25. Hamedi D, Taghizadeh G, Lajevardi L, Binesh M, Ghomashchi H, Talebian S. Correlation between sway parameters of center of pressure in quiet standing with eyes open and eyes closed, functional balance tests and symmetry index in chronic hemiparesis patients. Novin Rehab Journal 2013; 7(4): 38-47.

26. Karlsson A, Frykberg G. Correlations between force plate measures for assessment of balance. Clinical Biomechanics 2000; 15:365-369.

27. Niam S, Cheung W, Sullivan PE, Kent S, Gu X. Balance and Physical Impairments After Stroke. Archives of Physical Medicine and Rehabilitation 1999; 80: 1227-33.

28. Pyöriä O, Era P, Talvitie U. Relationships Between Standing Balance and Symmetry Measurements in Patients Following Recent Strokes (<3 Weeks) or Older Strokes (>6 Months). Physical Therapy 2004; 84: 128-136.

29. Gil AW, Oliveira MR, Coelho VA, Carvalho CE, Teixeira DC, da Silva RA Jr. Relationship between force platformand two functional tests for measuring balance in the elderly. Brazilian Journal of Physical Therapy 2011; 15(6): 429-35.

30. Desai A, Goodman V, Kapadia N, Shay BL, Szturm T.Relationship Between Dynamic Balance Measures and Functional Performance in Community-Dwelling Elderly People. Physical Therapy 2010; 90: 748-760.

31. Remaud A, Boyas S, Lajoie Y, Bilodeau M. Attentional focus influences postural control and reaction time performances only during challenging dual-task conditions in healthy young adults. Experimental Brain Research Springer-Verlag 2013.

32. Resch JE, May B, Tomporowski PD, Ferrara MS. Balance Performance With a Cognitive Task: A Continuation of the Dual-Task Testing Paradigm. Journal of Athletic Training 2011; 46(2): 170-175.

33. Alexander NB, Hausdorff JM. Linking thinking, walking, and falling. Journal of Gerontology: Biological Sciences and Medical Sciences 2008; 63: 1325-1328.

34. Bootsma-van der Wiel A, Gussekloo J, de Craen AJ, van Exel E, Bloem BR, Westendorp RG. Walking and talking as predictors of falls in the general population: the Leiden 85-plus study. Journal of the American Geriatrics Society 2003; 51: 1466-1471.

35. Rochester L, Hetherington V, Jones D, Nieuwboer A, Willems AM, Kwakkel G, Van Wegen E. The effect of rhythmical cues on walking during a simple and dual functional motor task in a complex environment in people with Parkinson's disease. Archives of Physical Medicine and Rehabilitation 2005; 86: 999-1006.

36. Springer S, Giladi N, Peretz C, Yogev G, Simon ES, Hausdorff JM. Dual-tasking effects on gait variability: the role of aging, falls, and executive function. Movement Disorder 2006; 21: 950-957.

37. Yogev-Seligmann G, Hausdorff JM, Giladi N. The role of executive function and attention in gait. Movement Disorder 2008; 23: 329-342.

38. Plotnik M, Giladi N, Dagan Y, Hausdorff JM. Postural instability and fall risk in Parkinson's disease: impaired dual tasking, pacing, and bilateral coordination of gait during the "ON" medication state. Experimental Brain Research Springer-Verlag 2011.

39. Yogev G, Giladi N, Peretz C, Springer S, Simon ES, Hausdorff JM. Dual tasking, gait rhythmicity, and Parkinson's disease: which aspects of gait are attention demanding? European Journal of Neuroscience 2005; 22: 1248-1256.

40. Newton RA. Validity of the Multi-Directional Reach Test: A Practical Measure for Limits of Stability in Older Adults. Journal of Gerontology 2001; 56(4): 248-252.

41. Smithson F, Morris ME, Iansek R. Performance on Clinical Tests of Balance in Parkinson's Disease.Physical Therapy 1998; 78: 577-592.

42. Morris S, Morris ME, Iansek R. Reliability of Measurements Obtained With the Timed "Up & Go" Test in People With Parkinson Disease. Physical Therapy 2001; 81: 810-818.

43. Azad A, Taghizadeh G, Khaneghini A. Assessments of the Reliability of the Iranian Version of the Berg Balance Scale in Patients with Multiple Sclerosis. Acta Neurol Taiwan 2011; 20: 22-28.

44. Salavati M, Negahban H, Mazaheri M, Soleimanifar M, Hadadi M, Sefiddashti L, et al. The Persian version of the Berg Balance Scale: inter and intra-rater reliability and construct validity in elderly adults. Disability and Rehabilitation 2012; 34(20): 1695-8.

45. Ng SS, Ng PC, Lee CY, Ng ES, Tong MH. Walk way lenghts for measuring walking speed in stroke rahabilitation. Journal of Rehabilitation Medicine 2012; 44: 43-46.

46. Salavati M, Mazaheri M, Negahban H, Ebrahimi I, Jafari AH, Kazemnejad A, et al. Effect of Dual-Tasking on Postural Control in Subjects With Nonspecific Low Back Pain. SPINE 2009; 34: 1415-1421.

47. Radomski M, Latham CT. Occupational therapy for physical dysfunction. Lippincott Williams & Wilkins 2008.

48. Salavati M, Hadian MR, Mazaheri M, Negahban H, Ebrahimi I, Talebian S, Jafari AH, et al. Test–retest reliabty of center of pressure measures of postural stability during quiet standing in a group with musculoskeletal disorders consisting of low back pain, anterior cruciate ligament injury and functional ankle instability. Gait & Posture 2009; 29: 460-464.

49. Pereira LC, Botelho AC, Martins EF. Relationships between body symmetry during weight-bearing and functional reach among chronic hemiparetic patients. Brazilian Journal of Physical Therapy 2010; 14(3): 259-66.

50. Lehmann JF, Boswell S, Price R, Burleigh A, deLateur BJ, Jaffe KM, et al. Quantitative evaluation of sway as all indicator of functional balance in post traumatic brain injury. Archives of Physical Medicine and Rehabilitation 1990; 71: 955-962.

51. Maki B, Fernie G. A system identification approach to balance testing. Progress in Brain Research 1988; 76: 297-306.

52. Holbein-Jenny MA, McDermott K, Shaw C, Demchak J. Validity of functional stability limits as a measure of balance in adults aged 23–73 years. Ergonomics 2007; 50(5): 631-646.

53. Hughes MA, Duncan PW, Rose DK, Chandler JM, Studenski SA. The Relationship of Postural Sway to Sensorimotor Function, Functional Performance, and Disability in the Elderly. Archives of Physical Medicine and Rehabilitation 1996; 77: 567-72.

54. Sawacha Z, Carraro E, Contessa P, Guiotto A, Masiero S, Cobelli C. Relationship between clinical and instrumental balance assessments in chronic post-stroke hemiparesis subjects. Journal of NeuroEngineering and Rehabilitation 2013; 95(10).

55. Huxham FE, Goldie PA, Patla AE. Theoretical considerations in balance assessment. Australian Journal of Physiotherapy 2001; 47: 89-100.

56. Shumway-Cook A, Woollacott M. Clinical management of the patient with a postural control disorder. In: Shumway-Cook A, Woollacott M, editors. Motor control: translating research into clinical practice. 3rd edn. Philadelphia: Lippincott Williams & Wilkins 2007; 257–295.