Functional analysis of postural balance in Parkinson's disease patients

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ABSTRACT

Parkinson disease (PD) is characterized by a loss of dopaminergic neurons in the substantia nigra pars compact, whose diagnosis is based on the presence of a hard-bradicinetic syndrome, resting tremor, postural instability, akinesia and festination gait. This study aimed to investigate, from functional activity tests, postural stability and balance of patients with PD. The sample comprised 34 volunteers, divided into two groups, Parkinson Group, composed of 17 patients with clinical diagnosis of idiopathic PD and Control Group with 17 healthy subjects without musculoskeletal disturbances. Balance and postural stability were assessed in both groups by using functional activity tests: Figure 8 test, Timed Up and Go test, sit and lift, bearings, Turning 360º, Functional Reach Test and Berg Balance Scale. The mean age of Parkinson Group and Control Group was respectively 64.11 ± 10.7 and 60.47 ± 8.53 (p=.42). Control Group obtained better results in the performance of tests: Figure 8 (p=.0003), Timed Up and Go (p=.0001), bearing (p=.0002), Functional Reach Test (p=.029) and Berg Balance Scale (p=.0001) between the groups. The outcomes of this study confirm that both balance impaired and loss of mobility are among the main consequences of PD.

Introduction

Nowadays, the aging is a great challenge for public health. In worldwide, it is estimated that about one million of people overpass 60 years old each month, and should exist two billion elderly people in the world in 2050, which two thirds will be living in development countries, including Brazil. According to Oliveira et al [1], the number of people aging 60 and over grows much faster than that of all other age groups in Brazil.

In parallel to the changes observed in the population pyramid, aging diseases have gained greater relevance in the society, whereas increase in longevity brings higher trend to chronic degenerative diseases, such as Parkinson`s Disease (PD). Such diseases are often found among elderly people, who despite living longer, they have more chronic conditions, which are directly related to bigger functional disability [2].
PD is characterized as an age-related neurodegenerative chronic disease, which prompts to graduate fall of motor function with disease progression. PD is considered the second neurodegenerative disease more common after Alzheimer`s disease [3,4].

About 1% to 2% of population over 65 years old develops PD. This prevalence increase 3% to 5% in patients with 85 years or more; therewith, PD becomes increasingly common in countries population is overcrowding [2].

In PD occurs dopaminergic neurons damage in substantia nigra pars compacta (SNpc) that causes a significant deficit in neurotransmitter dopamine in the striatum. Consequently, nigrostriatum neurodegeneration generates motor dysfunctions in patients with PD, such as resting tremor, akinesia, bradykinesia, rigidity and postural instability [5,6].

The average age of PD appearance is from 50 to 60 years old, and life expectation affected by this disease is almost normal. However, debilitating situations incapacitate these individuals gradually over decades. Even under proper medication for the disease, frequent and recurrent falls lead to devastating consequences such as fractures, second most common reason that lead people with PD to be admitted to hospitals [7,8].

It is believed that there are changes in equilibrium reactions in PD patients due to the degeneration of glutamatergic neurons in pedunculopontine nucleus plus atrophy and degeneration of the basal ganglia, generating an exacerbated inhibitory pattern. This degeneration causes difficulty to modulate strategies of equilibrium in PD patients [9].

Moreover, there is a constant conflict in central sensory processing, which presents intact visual and somatosensory information and exacerbated galvanic vestibular reactions, which also interferes in balance [10].

These changes have been related to the high rate of falls in these individuals, and they almost always increase functional disability and morbidity. Another factor that also contributes to the occurrence of falls is the difficulty provided by the physical environment, such as holes, stairs and uneven ground [11]. The prevention of this condition represents a major challenge for the individual himself/herself, his/her family, for health professionals and for the public health.

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Studies show that 68% of people with PD tended to fall and 46% of them will experience recurrent falls each year, these rates are about two times more than the general population of elderly [12].

Fear of falling is also higher in PD patients compared to healthy elderly; it compromises the quality of life and performance of daily activities. Moreover, this context predisposes to decreased muscle strength and postural balance [7].

In this way, physical therapy has demonstrated beneficial results in reducing injuries from PD. Canning et al. [7] revealed that therapeutic program based on low intensity exercises improved aerobic capacity, flexibility, strength, coordination, and balance in individuals with PD. However, before the implementation of physical therapy programs it is important to know the motor damage, including the balance deficit in patients with this disease. It is necessary, therefore, to investigate the difference of this factor between healthy and PD individuals by using functional tests.

Given the above and in the view of the neuromotor changes in PD patients, especially those related to balance, which bring potential risks in the equilibrium and predisposition to falls, the purpose of this study was to evaluate balance and postural stability and quantify functional changes of balance in individuals with Parkinson's Disease.

Methods

Subjects

The sample was composed of 34 subjects, whereupon 17 were patients with idiopatic PD, treated with levodopa, 2 and 3 staging according to Hoehn and Yahr Scale (HY) [13], stable with respect to anti-parkinsonism therapy, recruites from outpatient neurology at the Clinical Hospital at the Federal University of Sergipe; and 17 healthy subjects without musculoskeletal changes, recruited in Aracaju, State of Sergipe, Brazil.

Inclusion criteria for PD patients and healthy subjects were: both genders; age between 60 and 80 years old; motor flutuations; conventional antiparkinsonism therapy, excluding deep cerebral stimulation or previous palidotomy and talamotomy; absence of psychiatric condition, cognitive decline or dementia that influences communication; absence of disorder in one of these following systems: vestibular, musculoskeletal, neuromuscular, cardiopulmonar, recent or not solved that could be affect mobility or ability to get around; capacity to remain standing up at least for ten minutes; ability to walk independently, with or without auxiliary devices; not be under other physical therapy intervention [14].

The inclusion criteria for the healthy subjects were: both genders, age between 60 and 80 years old; absence of psychiatric condition, cognitive decline or dementia that influences communication; absence of disorder in one of these following systems: vestibular, musculoskeletal, neuromuscular, cardiopulmonar, recent or not solved that could be affect mobility or ability to get around; capacity to remain standing up at least ten minutes; ability to walk independently, with or without auxiliary devices; not be under physical therapy.

The subjects with PD and healthy controls were excluded when: clinic or physical examination showed scores were less than 24 on the Mini-Mental State Examination (MMSE); systemic conditions which interfere in study participation; musculoskeletal damage or excessive pain on any joint that could limit participation. For all participants with PD, all drugs were kept as prescribed by the neurologist, and caracthterized beween 1 to 3 Hohen&Yahar Scale.

Ethic Aspects

The present study was approved by the Ethic Committee on Human Research at the Federal University of Sergipe. Data collection was started after the participants signed the informed consent.

Study Design

This is a cross observational study. Subjects were enrolled into two groups: Parkinson Group and Control Group. Parkinson group was composed of 17 patients with idiophatic PD, minimum duration of one year. The patients of Parkinson group underwent a functional assessment of balance and postural stability during "on" period of antiparkinsonism therapy.

Control group was comprised of 17 healthy participants, without musculoskeletal disorders. The volunteers of this group also underwent a functional assessment of balance and postural stability.

Blood pressure and heart rate were measured in both groups before to performing functional and cognitive assessment.

Measurements

Balance assessment was performed through functional activities which assess functional mobility: Figure of Eight test [15], Timed Up and Go test (TUG) [16, 17], Rollover task, 360 degree turn-in-place task [18], Functional Reach test [19], sitting and standing test, Berg Balance Scale [20]. The values found in these tests were compared to the Parkinson Group with the values found in the control subjects. All tests were performed with individuals of bare feet and in case of visual disturbances; tests were performed with the use of corrective lenses suitable.

Figure of Eight test

The Figure of Eight test timed subjects walking in a figure-8 trajectory. The figure-8 trajectory was marked with 4 cm-wide tape on the floor, each loop having an internal diameter of 163 cm. The time to walk two complete cycles was measured with a hand-held stopwatch. The subject started in the center of the figure-8 and the onset time was based on the first detectable movement of the subject following a "Go!" command from the experimenter. Steps outside or inside the line were quantified. The task was performed twice, but the first test was considered as a training trial and was not used for analysis [15].

Timed up and Go test (TUG)

In the Timed Up and Go test (TUG) subjects began from a seated position, rose from the chair, walked 3 m straight ahead, turned 180 degrees, returned to the chair, and sat down. The entire sequence was timed with a stopwatch and all subjects performed the TUG three times. The first trial was considered as a training trial and the mean of the second and third trials was used for the analysis [16,17].

Rollover Task

The rollover task began with subjects in supine position on a therapy mat. The subjects were instructed to execute a 360 deg-rolling movement to the left as fast as possible after a "Go!" command (stopwatch started). When the evaluator determined that the maneuver had reached a full 360 deg, the subject immediately received a "Return" command and the subject rolled 360 deg to the right as fast as possible to the supine position. A stopwatch was used to time the duration of

the task. The task was performed twice, and the second trial duration was used for analysis [18].

360 degrees turn-in-place task

A 360 degrees turn-in-place task was timed using the motion analysis system with reflective markers on the subjects' feet. The subjects were instructed to turn in their preferred direction 360 degrees when they were ready to do so (self-initiated). Turn duration was computed from the first movement of the toe or heel off the floor until the last vertical contact of the foot (toe or heel) on the floor after a full 360 degrees turn [18].

Functional Reach Test

Subjects stood beside a horizontally oriented measuring tape on the wall at their shoulder level. The subjects were oriented to stay with shoulders perpendicular to the measuring tape and both arms stretched out in a 90° shoulder flexion. The subjects were then instructed to "reach forward as far as you can without losing balance or taking a step" and the distance (in centimeters) they reached from the initial position was measured [18].

Sitting and Standing Test

This test was performed using a firm chair without armrest. The time between the initial seated position and the final seated position at the end of 3 repetitions was recorded on a self-selected rate. All participants performed 3 sets of 3 attempts. A total of nine replicates are recorded and recording the average subsequently [19].

Berg Balance Scale (BBS)

This test analyzes balance and gait impairments and falls in elderly. The Berg Balance Scale (BBS) is considered the standard reference for assessing balance and determining fall risk. Scale scores were related to clinical judgements and self-perceptions of balance, laboratory measures of postural sway and external criteria reflecting balancing ability. The BBS is a 14-item test, with each item rated from 0 (signifying poor balance) to 4 (signifying better balance). A perfect score is 56 [20,21].

Hip Flexion Strength

The hip flexion strength was recorded in dominant lower limb using a hand held digital dynamometer (model: IP-90DI, Impac®, São Paulo, SP, Brazil). Participants were positioned sitted on a chair with their hips and knees flexed to 90 deg. The thigh and knee were immobilized to avoid compensation of adductor muscles. The dynamometer was positioned perpendicular to the distal section of the femur. Normalization of the data was standardized so that the force, in Newtons (N), was multiplied by the distance between the axis of rotation of the joint and the point of application of force, in meters (m) and divided by body weight (kg) [22,23]. Therefore, the result of muscular strength consisted unit represented by Nm/Kg. The peak value was obtained from four test trials [24].

Statistical Analyses

Initially, data were transported to a spreadsheet program Excel data for Windows 2010 and then to SPSS, version 17, for the following analyzes: (a) descriptive: with tables of frequency measures position (mean, median, minimum and maximum) and dispersion (standard deviation and standard error of the mean), (b) normality test to identify whether the data were parametric or nonparametric (c) comparison: test T. Data with $p \leq .05$ were considered statistically significant.

Results

Thirty-four participants underwent in this study, both genders, distributed into two groups: (1) Parkinson Group (PG), n=17, age: 64.11±10.70 years old, BMI: 26.54±4.25 kg/m^2; and (2) Control Group (CG), n=17, age: 60.47± 8.53 years old, BMI: 26.96±5.42 kg/m^2. There was no statistical difference between the groups regarding to age, weight, height, body mass index, mental state and depression (Table 1). In the sample, it was observed that the initial common symptom was resting tremor in the left hemi-body 63.63%. Patients in Parkinson Group have disease stages between 1 and 3 according to the Hoehn and Yahr Scale and all of them were using conventional antiparkisonism therapy, treated with levodopa.

Table 1. Demographic characteristics in the Parkinson and Control Groups.

Baseline Data	Parkinson	Control	P
	N=17	N=17	
Age (years)	64.11(2.61)	60.47(2.00)	0.42
Weight (kg)	65.54(2.79)	68.67(3.20)	0.47
Height (cm)	157.24(0.17)	159.81(0.19)	0.31
BMI	26.54(0.81)	26.96(1.30)	0.79
MMSE	24.83(0.69)	25.06(0.52)	0.88
BDI	13.55(1.88)	13.62(1.37)	0.79

Mean(DP) and P value. T test for independent samples. Without significance between groups. BMI: body mass index, MMSE: mini mental state examination, BDI: Beck depression inventory.

Functional capacity outcomes were obtained through different functional tests. In the Figure of Eight test, the average time to perform the activity was significantly higher in Parkinson group (43.56(5.50) seconds) than in the control subjects (16.81(0.70) seconds) (p=0.0003). In the Timed Up and Go test (TUG), the average time required to perform the entire test was also significantly higher in Parkinson (24.18(2.80) seconds) than in Control group (10.02(0.30) seconds) (p=0.0001). For the sitting and standing test, the results observed were 12.82(1.00) and 6.72(0.30) seconds for PD subjects and controls, respectively, indicating a longer time for completing the functional testing by patients with Parkinson disease (Figure 1).

There was no significant difference in the spent time on the 360 degrees turn-in-place test execution between groups (Parkinson: 7.00(0.72) seconds, and Control: 2.75(0.21) seconds). The average time to perform the rollover test was significantly higher in Parkinson (20.96(3.20) seconds) than in Control group (4.94(0.31) seconds) (p =0.0002) (Figure 1).
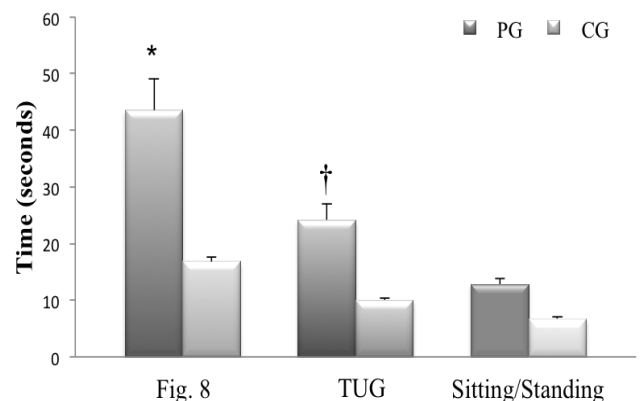
Figure 1. Spent time (seconds) to perform the tests: Figure of Eight test (Fig. 8), Timed Up and Go test (TUG-test) and Sitting and standing test, 360 degrees turn-in-place test (360 deg.) and Rollover test for patients in Parkinson Group and Control Group. Mean(DP). T-test for independent samples. *p=0.002, †p=0.0001.

In the Functional Reach test, Parkinson group showed smaller distance reach, 19.44(1.72) cm, than Control group: 25.31(2.01) cm, p=0.029, Figure 2.
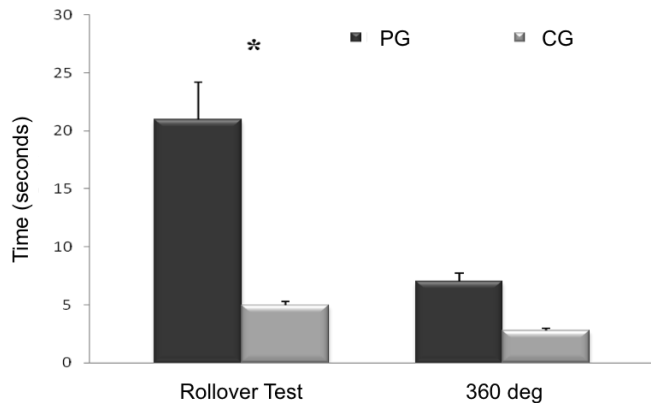
Figure 2. Distance (in centimeters) in the Functional Reach test in Parkinson Group and Control Group. Mean(DP). T test for independent samples. *p=0.029.

In Berg Balance Scale test we observed lower body balance in Parkinson group, 46.35(1.80) when compared to Control: 55.06(2.01), p=0.0001, Figure 3.

Table 2 shows the results of the statistical tests used to analyze the relationship between the results of functional tests (Timed Up and Go, rollover turn-in-place, and figure 8) and hip flexion strength in right lower limb. A significant association was observed in all of tests in both groups; it shows that strength could be influence functionality, mainly in people with motor delay.
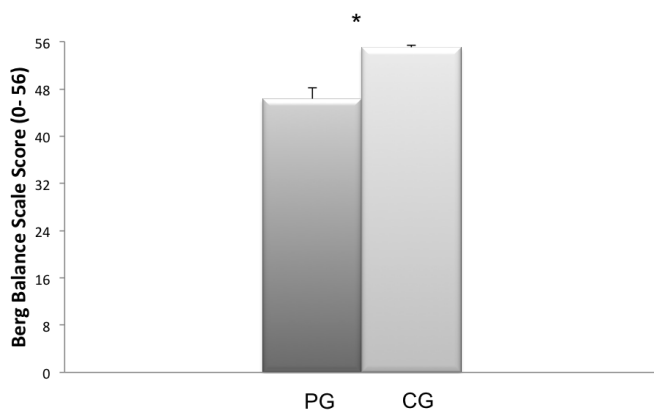
Figure 3. Berg Balance Scale (BBS) in Parkinson Group and Control Group. Mean(DP). T test for independent samples. *p=0.0001.

Table 2. Correlation between Functional tests (Velocity: Timed Up and Go (TUG), Balance and velocity: Rollover turn-in-place (ROLLOVER), and Balance and velocity: figure 8 (FIG. 8)) and strength: hip flexion strength in dominant lower limb.

Variables	Parkinson Group		Control Group	
	p	r	p	r
Time (TUG Test) x Hip Flexion	0,0001	-0,8581	0,05	-0,8584
Time (Rollover Test) x Hip Flexion	0,0001	-0,8581	0,05	-0,8584
Time (Figure 8 Test) x Hip Flexion	0,0002	-0,8581	0,05	-0,8584

Mann-Whitney test for independent samples. Spearman Test. *p≤0.0002.

Discussion

The Figure of Eight and TUG tests assess ability of patients to walk into different trajectories. The circuit in Figure 8 is a curvilinear path that requires balance and coordination for the patient to change direction and guidance along the way. The results showed that patients with Parkinson`s disease in period "on" medication performed the figure of 8 test in a larger time than controls, showing significant difference in time to perform the tests between groups.

This test requires continuous turning during gait, with emphasis on precision, since patients are request to walk on a path in line 8. Because of that, parkinsonians spent greater time to perform the test than the controls, due to the nature of the problems of mobility in PD, with turns in block, against-rotation of the trunk deficit, whereas in healthy individuals, the dissociated movement from the trunk, such as the anticipated movement of the head, is performed effectively [25].

The straight path of TUG test, as proposed by Podsialdlo and Richardson [17], assesses functional mobility, balance, mobility with change from sitting to standing, stability in walking, changing direction and walking speed. In this way, this test is capable of detecting changes in motility in patients with PD [16].

In a study by Gobbi et al. [21], subjects had spent time in TUG test less than 20 seconds, which indicates good performance and classifies individuals as independent [17,26]. Contraryly, Schilling et al. [27] found values for PD patients less than 10 seconds with disease staging equal to 2 on the Hoehn and Yahr (H&Y) scale, also indicating an adequate performance in the test.

In our study, we observed more than 20 seconds to performe the test in parkinsonians than about 10 seconds for the controls. Thus, it demonstrates greater motor dysfunction in patients with PD in our sample, unlike previous studies. The TUG test can be used to detect different performances between people with and without PD as was done in our study [16].

When we investigated the reliability and sensitivity of the scores of TUG test, we detected motility changes in patients with idiopathic PD compared to healthy individuals. The time required for completion the test was greater for subjects with PD [16,17].

Contraryly, Zampieri et al. [28] found no significant difference in TUG test between subjects with early stage PD, never treated with antiparkisonism therapy, and healthy control subjects. In this case, the disease stage of the patients must have contributed to this result, according to the H&Y scale, patients in the early stage of the disease show no signs or have only a unilateral or unilateral and axial body commitment, contrasting the subjects in our study, which have bilateral involvement of the body [13].

The TUG test combines sequential motor actions that require components of functional capacity, such as strength, flexibility and agility [17,18,19,21]. These components are deficient in PD due to rigidity, bradykinesia and akinesia. Like Schilling et al. [27], this study observed relationship between strength and time in TUG test. This study covered relationship between functional tests (TUG-test, figure of 8 test, and rollover turn-in-place task) and hip flexion strength in dominant lower limb. The results showed that these factors are important for the performance of tasks such as standing, sitting, walking and turning [29]. Therefore, greater muscle strength, flexibility and agility can help to improve

performance in activities of daily living, plus improve functionality [9,30].

In relation to the results from the evaluation of the sitting and standing test between parkinsonians and controls, the average of required time to perform the test in parkinsonians was approximately two-fold than controls. The small sample size of this study may have contributed to the lack of statistically significant differences between the groups in this test.

Sitting and standing are among the most routinely practiced activities in daily life, and the performance of these actions has a close relationship with the risk of falling [19,31], which is common in people of higher ages, as in our study. Minimum levels of muscle strength, coordination, balance and flexibility are needed to show the successful execution of motor actions performed on the test [13,32]. Therefore, we suggest that constant physical therapy, including early-stage PD, in order to prevent excessive advancement of the sequelae and to minimize motor disorders caused by disease.

The Berg Balance Scale is widely used in the elderly population as a reliable tool to measure functional stability [20,33] and present a strong association with well established measurement tools for people with PD, such as motor subscale of the Unified Scale Evaluation for Parkinson's disease (UPDRS) and modified H&Y scale [21].
Considering the Berg Balance Scale (BBS), Gobbi et al. [21] found values close to 50 points in PD patients in pre and post intervention of an exercise program. Whereas, Rochester et al. [34] observed a significantly lower balance in elderly patients with PD compared to healthy elderly subjects, matching our findings.

Our data demonstrated that parkinsonians have significant balance deficits. The application of BBS is important to define the risk factors for loss of independence and episodes of falls in the elderly, related to impaired balance and mobility in the population studied.

The difficulty in rolling supine and perform transfers of decubitus, as well as the development of turn-in-place in parkinsonians, is due to a muscle rigidity and block-movement without dissociation waistlines, which are characteristics in PD. Usually, functional results of stiffness include a bending posture, lack of rotation of the trunk and reduced range of motion during the postural transitions [9,35].

Moreover, the sudden akinesia or freezing defined by the abrupt loss of the ability to initiate or sustain a specific motor activity may occur as a hesitation of the movement beginning or determine a sudden slowdown of movements in lower limbs, which may lead to falls [36]. These facts may explain the longer spent time in rollover and 360 deg turn-in-place tests in parkinsonians.

The functional reach test reflects the ability of the subject to move voluntarily to the limits of anterior stability [19]. Likewise Franzén et al. [18], our findings showed lower performance by the parkinsonians represented by the lower anterior advancement. This may be due to a postural instability and consequent abnormalities related to posture with anterior tilt of the trunk, semiflexion of elbows and knees and lack of postural reflexes, characteristics of PD [37,38].

Our findings highlight the motor damage caused by PD as to balance and postural stability. The decrease in the balance and postural stability, reduction of postural reflexes, and difficulty in performing transfers and changing from different positions directly influence the lowest quality of life of these patients.

The aim of this study was to assess the balance in PD patients compared to healthy individuals, it is important so that there to be a special attention in the evaluation and treatment in patients with PD. Thus, there is an evident need for achievement tests in pretreatment whith sensitive detection of such deficits and behaviors aimed at improving Parkinson's disease disabilities.

Physical therapy has proven to be effective in improving the changes arising from the DP, as decreased strength and balance that added to the freezing of gait and postural instability predispose to increased risk of falls in PD individuals [38].

Crizzle and Newhouse [39] showed that exercise program improve motor condition in PD patients, furthermore it increases the performance of daily activities and can promote gains in functional balance. This intervention prevents falls not only in olderly, but also in PD patients [40].

Smania et al. [41] developed a survey to evaluate the effects of balance training on postural instability in PD patients. Sixty-four PD patients were divided into 2 groups (experimental group to balance training and control group for physical exercise), which received 21 sessions of physical therapy, during 50 minutes. BBS was one of assessment used before and after treatment. At the end of treatment, there was significant improvement in body balance in the experimental group, concluding that a program of balance training can improve postural instability in PD patients.

This study was limited due to a small sample size, envolving volunteers with different times of onset of the disease and those taking different doses of conventional antiparkinsonism therapy. However, we had great difficulty in patient compliance due to difficulty to come to the clinic and participate assiduously sessions, for various reasons, among which the lack of interest, especially family.

Conclusion

The assessment of balance and postural stability demonstrated greater impairment of balance and damage of mobility in subjects with PD, these symptoms contribute to reduction of functional independence, compromising the performance of daily activities, and, as a consequence, they reduce functional capacity, that increases the susceptibility to falls.

We suggest that individuals with PD join into physical therapy programs, to increase muscular strenght, flexibility, proprioception, and body balance. In order to decrease the effects of the disease, physical therapy promotes the obtainment the benefits from treatment to optmizing the balance and postural stability.

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