

## Postural stability in Parkinson's disease patients

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*Purpose:* The aim of the study was to analyze postural stability in Parkinson's disease patients. A total of 32 subjects were tested, including 26 (81.25%) women and 6 (18.75%) men. These were patients with advanced, idiopathic Parkinson's disease. The disease duration was over 5 years. *Methods:* The study was conducted in the Posturology Laboratory at the Department of Medicine and Health Sciences, Jan Kochanowski University in Kielce (Poland). The Biodex Balance System was used for evaluation of postural stability. Postural Stability Testing was performed with both feet positioned on a stable surface with the eyes open. *Results:* The Overall Stability Index in the whole group was 0.5°. The higher Overall Stability Index in women is indicative of slightly worse postural stability compared to men, although in both groups, it was within norms ( $Z = 2.0545$ ,  $p = 0.0399$ ). Anterior-Posterior Overall Stability Index (A/P) was an average of 0.35°. The Medial-Lateral Overall Stability Index (M/L) was an average of 0.27°. Both women and men were observed to have higher postural sway in the sagittal plane than the frontal plane. The vast majority of the subjects maintained in Zone A during testing (99.94%), and was slightly bent backwards to the right and in Quadrant IV (61.53%). *Conclusions:* Regular control of postural stability in Parkinson's disease patients is significant due to the risk of falls.

*Key words:* postural stability, Parkinson's disease, Postural Stability Test

### 1. Introduction

Parkinson's disease affects 1% of the population aged 40 to 60, but occurs also in younger individuals. In Poland, about 80,000 people suffer from this disease [12]. Its symptoms are due to degenerative necrosis of the nerve cells in the black substance (Latin: *substantia nigra*) and other areas of cerebral colouring. Neuropathic symptoms correlate with the clinical image of the disease. As the disease progresses, the efficacy of pharmacotherapy decreases [2], [7]. There are side effects of the on-off phase (rapid changes in motor function). Although the patient is able to move quite freely at the time of consuming therapeutic doses, their motor capacity decreases rapidly when the drugs stop working [5]. These clear changes are remi-

niscent of turning a light "on" and "off". Initially, these phases largely depend on the time of ingestion, but over time, their changes become more random [8]. Postural neural disorder is a significant symptom of Parkinson's disease as a chronic neurological disability [10], [13]. Maintaining vertical posture and control of the body is a multifaceted process based on the principles of mobility and correction. Behavioural postural stability is a dynamic process that consists in overcoming various disturbances [14]. These disturbances may result from internal and external environments. Progressive and chronic atrophic changes in CNS structures that control motor function and degenerative changes in vision, hearing, proprioception and the balance system disturb the stability of posture. Tendencies to fall occur, especially during rapid head movements [17]. In turn,

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this leads to impairment of motor activity and other consequences.

For clinical diagnosis of Parkinson's disease, the occurrence of two of the three major axial symptoms are required: resting tremor, bradykinesia and rigidity. Movement slowdown is a prerequisite for diagnosing the disease. The symptoms of Parkinson's disease in everyday life are manifested by difficulty in moving independently, performing tasks requiring precision, difficulty in starting and completing motions, balance disturbances and falls [19]. There is also a reduction in the range of motion in the joints of the lower limbs. Gait occurs in small strides, slow speed, shortening of the stride width and length. There are also difficulties in starting and stopping the gait and lack of contraction of the shoulder girdle relative to the hips and the work of the upper limbs. There are difficulties with proper rotation of the trunk during turning and walking [23]. Patients experience sudden loss of balance, ending with a fall (pulsion). There may be a preference to fall backwards (retropulsion), forwards (propulsion) or laterally (lateropulsion) [8]. Expansion of dual support time and reduced walking speed also appear. The so-called tunnelling symptom may occur, consisting of small steps before a narrowing on the path of movement. So-called freezing may also take place, i.e., sudden blockage during gait [15]. Often the patient cannot lift their foot off the floor to take another step. Sudden immobilization can cause a loss of balance. When a haltering in movement occurs at the time of turning or twisting, it may cause a fall [24]. Gait disorders are the most common cause of falls.

In the course of Parkinson's disease, due to, among others, muscle stiffness and motor slowdown, abnormal body posture and pathological gait patterns occur [19]. In the patient's posture a lot of different deformation can be observed, such as forward inclination of the head and cervical spine, deepening of chest kyphosis, flattening of lumbar lordosis, positioning of the shoulder joints in an extended position and their adduction as well as internal rotation, elbow joint flexion with pronation, flexion of the metacarpophalangeal joints, extension of the interphalangeal joints, thumb adduction, light abduction, flexion, internal hip rotation and light flexion of the knee joint. Due to the limitations in daily activity, individuals with Parkinson's diseases become less independent and their quality of life is reduced [9].

Rehabilitation in Parkinson's disease is no less important than pharmacological treatment. In general, patients with physical, cognitive and emotional disorders avoid physical activity, exclude themselves from family, social and occupational life [11]. The goal of

physiotherapy is to improve motor skills and physical ability so that these individuals may perform independent activities and live actively [20]. Its task is also to limit the symptoms, particularly motor slowdown, tremors, stiffness, and to improve quality of life [22]. At an advanced stage, physiotherapy supports coping with the progressive nature of the disability, prevents complications caused by immobilization and reduces dependency on caregivers [1]. The aim of the study was to analyze postural stability in Parkinson's disease patients.

## 2. Materials and methods

A group of 32 individuals, members of the Parkinson's Association in Kielce (Poland) were examined. The majority comprised of women totalling 26 (81.25%), while there were 6 men (18.75%). The study was conducted in November 2013 in the Posturology Laboratory at the Department of Medicine and Health Sciences, Jan Kochanowski University in Kielce. All patients were treated with Levodopa (L-DOPA, Latin: *Levodoprum*). The illness duration was over 5 years. The daily dose of L-DOPA was in the range 600–1000 mg/d. For 12 months, patients participated in physiotherapy classes. Systematically, twice a week for 45 minutes, they performed strengthening, balance, stretching, relaxing and breathing exercises, as well as motor-ability games and gait training. In order to analyze body mass, BMI and metabolic age the Tanita MC 780 MA body composition analyzer was used. The tool uses the method of bioelectrical impedance analysis.

The Biodex Balance System was used to assess postural stability. Postural Stability Testing was performed with both feet positioned on a stable surface with the eyes open. The platform was blocked, meaning it was inflexible and fully stable. After entering the patient's personal data and height into the system, their position was determined. For this purpose, the centreline of the foot and the platform axes were used as reference points. The position was determined by entering the feet setting angle on the monitor of the apparatus, using the centre line separately for the right and left foot.

The Postural Stability Testing consisted of three 20-second trials, separated by a 10-second interval. During the test, the patient's eyes were focused on the screen where the COP (center of pressure) appeared, which was a symbolic representation of the foot pressure centre. The task of the subject was to balance the

body so that the dot (COP) was in the centre of the circle visible on the screen, at the point of intersection of the coordinate axes. During the test, verbal correction of the patient was allowed. All parameters recorded by the posturographic platform were collected in a non-invasive manner and the device was safe for the group.

The following were used to assess postural stability:

- Overall Stability Index [°]. This indicator reflects the variability of the platform's position from the horizontal plane expressed in degrees during all movements in the test. Its high value is evidence of the large number of movements performed during the test. The norms for this indicator depend on the age of the subjects and are: age 17–35: 0.7–2.1°, age 36–53: 0.7–3.1°, age 54–71: 0.9–3.7°, age 72–89: 2.0–4.0°. Exceeding the norm may entail a risk of falling [3].
- Anterior-Posterior Stability Index [°] – reflects the variability of the platform's position for movements in the sagittal plane in degrees.
- Medial-Lateral Stability Index [°] – reflects the variability of the platform's position for the movements in the frontal plane in degrees.

The patient's score in the Postural Stability Test depended on the number of deviations from the centre, which means that the lower the result, the better the postural stability.

- % Time in Zone. This indicator designates the time spent by a patient in a given zone. The targeted Zones A, B, C and D are equal to the platform in-

clination. They are designed by concentric circles centred in the middle of the platform.

- Zone A – from zero to five degrees of deviation from the horizontal plane,
- Zone B – from six to ten degrees of deviation from the horizontal plane,
- Zone C – from eleven to fifteen degrees of deviation from the horizontal plane,
- Zone D – from sixteen to twenty degrees of deviation from the horizontal plane.

- % Time in Quadrant. This indicator designates the time spent by the patient in a given quadrant. The squares represent four quarters of the test graph between axes X and Y:
  - Quadrant I – right front,
  - Quadrant II – left front,
  - Quadrant III – left rear,
  - Quadrant IV – right rear.

Variables were verified for normal distribution with the Shapiro–Wilk test. Gender-related variables were compared with the Mann–Whitney U test. The use of this test did not require group equality, normal distribution or homogeneous variance. The test probability of  $p < 0.05$  was considered significant.

### 3. Results

The average age of the subjects in the whole group was 54.28 years with a standard deviation of 12.24.

Table 1. Results of analyzed anthropometric variables

Anthropometric variables	Gender	Arithmetic mean	Standard deviation	Minimum	Lower quartile	Median	Upper quartile	Maximum	Mann–Whitney U test
Age	Total	54.28	12.24	32.00	46.75	55.00	63.25	85.00	Z = 0.2659 p = 0.7903
	Female	54.58	11.30	32.00	47.50	55.00	62.25	85.00	
	Male	53.00	16.97	32.00	38.00	57.50	66.50	70.00	
Height [cm]	Total	165.5	8.10	150.0	159.5	164.5	170.2	184.0	Z = 3.7541 p = 0.0002
	Female	162.6	5.78	150.0	158.0	164.0	166.7	172.0	
	Male	177.8	3.71	174.0	175.2	177.0	179.5	184.0	
Weight [kg]	Total	66.14	11.05	48.30	58.10	65.60	74.05	89.00	Z = 3.2592 p = 0.0011
	Female	62.74	8.79	48.30	57.35	59.35	71.50	78.20	
	Male	80.85	7.15	71.50	75.55	81.15	86.75	89.00	
BMI	Total	24.12	3.49	17.50	21.65	23.10	26.00	32.30	Z = 1.4735 p = 0.1406
	Female	23.78	3.66	17.50	21.35	22.35	25.78	32.30	
	Male	25.57	2.41	22.90	23.58	25.35	27.43	28.70	
Metabolic age	Total	42.34	11.74	20.00	34.00	43.00	49.25	70.00	Z = 0.2175 p = 0.8278
	Female	42.35	12.03	20.00	34.00	43.00	49.00	70.00	
	Male	42.33	11.45	27.00	35.00	42.50	51.50	55.00	

The average age of the women was 54.58, with a standard deviation of 11.3, and the average age of the males was 53.3 with a standard deviation of 16.97. Body height [cm] of the subjects in the whole group was an average of 165.5 with a standard deviation of 8.1. The body height [cm] of the women was on average 162.6, with a standard deviation of 5.78, and for the males, the average was 177.8 with a standard deviation of 3.71. Body mass [kg] in the whole group was 66.14 with a standard deviation of 11.05. The women's body mass [kg] was 62.74 with an average deviation of 8.79, and for men, 80.85 with a standard deviation of 7.15. The BMI in the whole group was averaged at 24.12, with a standard deviation of 3.49. BMI for women was at an average of 23.78 with a standard deviation of 3.66, and for men, on average 25.57 with a standard deviation of 2.41. The metabolic age across the group was on average 42.34 with a standard deviation of 11.74. The metabolic age of women was on average 42.35 with a standard deviation of 12.03, and for men is was an average of 42.33 with a standard deviation of 11.45.

The mean value of the Overall Stability Index [°] across the group was equal to 0.5 with a standard deviation of 0.35. In the case of women, the mean value of this index amounted to 0.55 with a standard deviation of 0.37 while the average for men was about 0.3 with a standard deviation of 0.13. The higher Overall Stability Index in women is indicative of inferior postural stability compared to men. This indicator was within the norms (Table 2). The mean value of the Anterior-Posterior Index [°] in the whole group amounted to 0.35 with a standard deviation of 0.24. The mean value of this ratio was equal to 0.37 with a standard deviation of 0.26 in the case of women and 0.23 with a standard deviation of 0.1 in the case of men. The mean value of the Medial-Lateral Index [°] across the group equal to 0.27 with

a standard deviation of 0.25. The mean value of this ratio amounted is 0.3 with a standard deviation of 0.26 in the case of women and 0.13 with a standard deviation of 0.05 in the case of men. The mean value of the Percentage Time in Zone A [%] across the group was equal to 99.94 with a standard deviation of 0.25. In the case of women, the mean value of this index amounted to 99.92 with a standard deviation of 0.27 while the average for men was about 100 with a standard deviation 0. The mean value of Percentage Time in Zone B [%] across the group amounted to 0.09 with a standard deviation of 0.3. The mean value of this index equalled 0.12 with a standard deviation of 0.33 for the women. None of the tested men were in Zone B. None of the subjects were in Zone C or D (Table 3). The mean value of the Percentage Time (Table 4) in Quadrant I for the whole group [%] amounted to 19.72 with a standard deviation of 16.05. The mean value of this indicator was equal to 19.50 with a standard deviation of 16.10 in the case of women and 20.67 with a standard deviation of 17.33 in the case of men. The Percentage Time in Quadrant II [%] in the whole group was averaged at 5.81 with a standard deviation of 9.29. The mean value of this ratio amounted to 6.31 with a standard deviation of 10.24 for women and 3.67 with a standard deviation of 1.97 for men. The mean value of the Percentage Time in Quadrant III [%] across the group amounted to 12.94 with a standard deviation of 11.83. The mean value of this indicator was equal to 12.65 with a standard deviation of 12.28 in the case of women and 14.17 with a standard deviation of 10.59 in the case of men. Percentage Time in Quadrant IV [%] across the group was 61.53 with a standard deviation of 22.25. The mean value of this indicator was equal to 61.54 with a standard deviation of 23.64 in the case of women and 61.5 with a standard deviation of 16.56 in the case of men.

Table 2. Postural stability

Postural stability variables	Gender	Arithmetic mean	Standard deviation	Minimum	Lower quartile	Median	Upper quartile	Maximum	Mann-Whitney U test
Overall Stability Index [°]	Total	0.50	0.35	0.20	0.30	0.40	0.60	1.90	Z = 2.0545 p = 0.0399
	Female	0.55	0.37	0.20	0.30	0.50	0.60	1.90	
	Male	0.30	0.13	0.20	0.20	0.25	0.38	0.50	
Anterior-Posterior Stability Index [°]	Total	0.35	0.24	0.10	0.20	0.30	0.40	1.30	Z = 1.3825 p = 0.1668
	Female	0.37	0.26	0.10	0.20	0.30	0.40	1.30	
	Male	0.23	0.10	0.10	0.20	0.20	0.28	0.40	
Medial-Lateral Stability Index [°]	Total	0.27	0.25	0.10	0.10	0.20	0.30	1.10	Z = 1.7927 p = 0.0730
	Female	0.30	0.26	0.10	0.10	0.20	0.30	1.10	
	Male	0.13	0.05	0.10	0.10	0.10	0.18	0.20	

Table 3. Time maintaining within individual zones in percentages

Time within individual zones in percentages	Gender	Arithmetic mean	Standard deviation	Minimum	Lower quartile	Median	Upper quartile	Maximum	Mann-Whitney U test
Zone A [%]	Total	99.94	0.25	99.00	100.0	100.0	100.0	100.0	$Z = 0.6330$ $p = 0.5267$
	Female	99.92	0.27	99.00	100.0	100.0	100.0	100.0	
	Male	100.0	0.00	100.0	100.0	100.0	100.0	100.0	
Zone B [%]	Total	0.09	0.30	0.00	0.00	0.00	0.00	1.00	$Z = 0.8125$ $p = 0.4165$
	Female	0.12	0.33	0.00	0.00	0.00	0.00	1.00	
	Male	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Zone C [%]	Total	0.00	0.00	0.00	0.00	0.00	0.00	0.00	$Z = 0$ $p = 0$
	Female	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Male	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Zone D [%]	Total	0.00	0.00	0.00	0.00	0.00	0.00	0.00	$Z = 0$ $p = 0$
	Female	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Male	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

Table 4. Time maintaining within individual quadrants in percentages

Time within individual quadrants in percentages	Gender	Arithmetic mean	Standard deviation	Minimum	Lower quartile	Median	Upper quartile	Maximum	Mann-Whitney U test
Quadrant I (%)	Total	19.72	16.05	0.00	5.75	15.00	33.00	64.00	$Z = -0.0242$ $p = 0.9807$
	Female	19.50	16.10	0.00	6.25	14.50	33.00	64.00	
	Males	20.67	17.33	2.00	6.50	20.00	29.75	47.00	
Quadrant II (%)	Total	5.81	9.29	0.00	1.00	3.00	5.25	46.00	$Z = 0.4875$ $p = 0.6259$
	Female	6.31	10.24	0.00	1.00	2.00	6.00	46.00	
	Male	3.67	1.97	0.00	3.25	4.50	5.00	5.00	
Quadrant III (%)	Total	12.94	11.83	0.00	3.00	10.00	17.50	41.00	$Z = 0.6541$ $p = 0.5131$
	Female	12.65	12.28	0.00	3.00	9.00	16.75	41.00	
	Male	14.17	10.59	3.00	5.50	14.50	18.25	31.00	
Quadrant IV (%)	Total	61.53	22.25	11.00	44.75	62.50	76.75	96.00	$Z = 0.0000$ $p = 1.0000$
	Female	61.54	23.64	11.00	45.50	66.00	78.00	96.00	
	Male	61.50	16.56	42.00	48.75	61.00	72.50	84.00	

## 4. Discussion

Postural stability disorders are significant symptoms of Parkinson's disease as a chronic neurological disability. Comparison of distribution of anthropometric variables revealed significant differences between women and men regarding height ( $Z = 3.7541$ ,  $p = 0.0002$ ) and body mass ( $Z = 3.2592$ ,  $p = 0.0011$ ) (Table 1). For the postural stability variables, significant differences between women and men were related to the Overall Stability Index [ $^{\circ}$ ] ( $Z = 2.0545$ ,  $p = 0.0399$ ). The higher Overall Stability Index in women is indicative of slightly worse postural stability compared to men,

although in both groups it was within norms (Table 2). Postural sway was greater in the sagittal plane than the frontal plane. In the course of the test, most of the subjects were slightly inclined backwards and stayed in Quadrant IV. In other studies, however, changes in postural control in the form of muscle stiffness, motor slowdown in corrective and anticipatory reactions have been observed. Sensory integration disorders, slowing of gait, freezing and decreasing automation of gait and balance were also observed.

It has also been shown that Levodopa does not have a positive effect on postural abnormalities, therefore, patients require rehabilitation [16]. Studies conducted by other authors have shown that patients with

Parkinson's disease have a significant reduction in postural stability, lower scores in the LOS (limits of stability), lower values of functional balance reserves and greater postural sway compared to healthy individuals. Deterioration of postural control was strongly associated with a severe risk of falls [6]. In another study, it was analyzed whether postural stabilization responses can be improved and whether these modifications can be retained in a manner similar to that used in people without freezing in Parkinson's disease patients for whom slowdown leads to freezing. Both persons with freezing symptoms and without them have not improved their results nor made permanent changes to the postural response system with respect to the main variable, center of mass (COM). However, other results related to gait protection, including stability margin, stride length and pace, improved at similar levels in all groups. People with Parkinson's disease who have a tendency to freeze their movement have a reduced ability to improve their protective responses to some, but not all, variables [18].

In other studies, it was demonstrated that there were significant low to moderate correlations between postural responses and overall gait. Correlations were similar in the freezer and non-freezer subgroups. Freezers performed worse than non-freezers regarding all gait parameters and backward postural response items. Low to moderate relationships between gait and postural responses indicate the complexity of postural control and the potential involvement of different neural circuitry across these tasks. A better understanding of the relationships between gait and postural deficits in Parkinson's disease may be informative for the future development of targeted interventions to address these impairments [21]. In other studies, it was noted that patients with Parkinson's disease have better functional status and motor performance under on-drug conditions. However, the administration of Levodopa leads to greater postural sway. At baseline, the on-drug patients swayed significantly more than the control group during the gaze-shift tasks. As expected, acute L-DOPA administration did not increase eye, head, neck and lower back rotation of the patients during the gaze-shift tasks. Unexpectedly, Levodopa appeared to enable the patients to significantly increase the contribution of their postural control mechanisms (relative to controls) during the gaze-shift tasks. However, and as expected, this adjustment was not great enough to enable the patients to maintain their postural sway as well as the control group did. Overall, the administration of Levodopa seemed to destabilize the patients – especially with regard to the lower-back region [4]. Regular control of postural stability in

Parkinson's disease patients is significant because of the risk of falls in this group. The results of the Postural Stability Test were within the norms, which is indicative of the proper course of treatment and physical therapy of the study participants.

## 5. Conclusions

The higher Overall Stability Index in women is indicative of slightly worse postural stability compared to men, although the two groups were within norms. In the case of both women and men, postural sway was higher in the sagittal than frontal plane. The vast majority of the subjects being tested were in Zone A during the test, and were slightly bent backwards to the right being in Quadrant IV. Regular monitoring of postural stability in Parkinson's patients is important because of the risk of falls.

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