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Abstract: Background: Parkinsons's disease is characterized by progressive worsening of gait, posture and balance with disability in daily life activities and to improvement in chronic musculoskeletal pain, often in neck pain associated with worsening of balance. The aim of the study is to investigate the correlation between scoliosis, balance and cervical pain in Parkinson's disease. **Methods**: Cross-sectional, pilot study. A total of 16 Parkinson's patients were enrolled in the study. The Pain Visual analogue scale and the short form McGill pain questionnaire measured neck cervical pain; static balance, Tinetti, Berg Balance and Short Physical Performance Battery scales (SPPB) were used to evaluate dynamic balance. Whole-spine standard X-ray assess spinal scoliosis with Cobb angles measurement. An observational statistical analysis was performed with the patients subdivided into a non-scoliosis (NS) group and a true scoliosis (TS) group based on whether they presented a Cobb's angle below or ≥10°. **Results:** Frequency of neck pain in the NS group was 37% compared to 50% in the TS group. A non-statistically significant difference was found in terms of static, dynamic balance and cervical pain scores between NS and TS groups. **Conclusions:** Scoliosis, cervical pain and postural imbalance are significant yet often overlooked complaints in PD.

Keywords: Parkinson's disease; scoliosis; postural imbalance; pain

1. Introduction

Parkinsons's disease (PD) is a chronic neurodegenerative disorder characterized by progressive worsening of gait, posture and balance. Abnormal postures and spinal misalignment tend to reduce dexterity, disrupt gait, and interfere with daily life activities also increasing the susceptibility to musculoskeletal pain or discomfort [1]. This becomes particularly evident in more advanced stages of the disease where striking sagittal or coronal plane spinal deviations occur (e.g., anterocollis, scoliosis, camptocormia and Pisa syndrome) and are further worsened by the process of aging [2]. Behind the origin of these clinical signs some authors suggest several peripheral (e.g., muscle rigidity, myopathy and soft tissue changes) and central causes (e.g., proprioceptive disintegration, dystonia and medication effects). However, the precise mechanism remains unclear [3]. Spinal scoliosis is a common disorder in PD with a reported prevalence between 43% and 90% [4]. Several experiments of artificially induced hemiparkinsonism on animal models have been showing to induce scoliosis, suggesting the possibility that this condition may have a neurologic background in some cases [1]. It is largely known that spinal regions are not independent of one another, and that the alteration of one segment can have repercussion on the other segments [5]. A study of Topalis and colleagues [6] found a higher prevalence of neck pain in adults with idiopathic scoliosis. Shin et al. [7] has shown that neck pain is associated with excessive cervical lordosis, upper thoracic kyphosis and altered shoulder and scapular kinematic in young women with forward head posture [7]. In addition to spinal deformities, individuals with chronic pain were shown to display balance impairment in multiple studies [8,9].

Despite the significant functional and quality of life impact of cervical pain and the vulnerability of these patients to develop spinal deformities and postural instability, so far, very little attention has been paid in the assessment of the relationship between these factors. Therefore, in this study, we aimed to investigate whether a correlation between scoliosis, poor static and dynamic balance, and cervical pain exists in a group of patients affected by PD. To our knowledge no previous study has been published that investigated this kind of relationship.

2. Materials and Methods

For this pilot, cross-sectional study, 16 consecutive patients with idiopathic PD that presented a scoliotic posture were recruited from the Physical and Rehabilitation outpatient clinic of the Agostino Gemelli University Hospital of Rome between May and October 2022. Part of these patients has been included in our previous study [10]. The present study complies with the STROBE guidelines.

2.1. Eligibility Criteria

The inclusion criteria were a diagnosis of PD according to the criteria of the Brain Bank of London; Hoehn and Yahr stage II-III; absence of cognitive impairment (MMSE> 24/30); effective pharmacological control of the pathology; acceptance and signature of informed consent.

The exclusion criteria comprised: a diagnosis of atypical Parkinsonism; presence of a clinically diagnosed Pisa syndrome, poor pharmacological compensation of the disease; diagnosis of other neurological, neuromuscular diseases or osteo-articular pathologies; visual impairment or vestibular disorders.

2.2. Clinical Evaluation

2.2.1. Medical Examination

Patients that met the inclusion criteria underwent a medical examination during which anamnestic data were collected regarding the age, weight, height, Body Mass Index (BMI), disease duration and current PD treatment including daily dose of Levodopa. All the patients were examined in the morning during the “ON” pharmacological phase.

2.2.2. Radiographic Evaluation

Each patient underwent a standard whole-spine X-ray in two planes (antero-posterior and lateral) in orthostatism. A senior radiologist evaluated the radiological images for the presence of spinal scoliosis and other deformities. To avoid misinterpretation with Pisa syndrome, which is a reversible lateral bending of the trunk, scoliosis was defined as the presence of a radiographic Cobb’s angle of at least 10° on the coronal plane, with or without vertebral rotation, that is not corrected by passive movement or supine position [3]. The curve was classified according to the location of its apex (most lateral vertebra) and its extremities (most peripheral upper and lower vertebrae), the direction of the convexity (right or left) and the curvature range (broad or narrow). The presence of other pathological findings in the coronal (e.g., compensation curve) or sagittal plane (e.g., kyphosis, lordosis, listhesis, etc.) was also reported when present.

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2.2.3. Stabilometric Evaluation

Static balance was assessed through a standardized stabilometric exam performed on a 'Prokin PK 254 P' device produced by TecnoBody Srl. (Dalmine, BG, Italy). The device consists of a static platform (47 cm in circumference) with four piezoelectric sensors positioned at the extremities of the four cardinal points. The temporal resolution was 0.01 seconds, and the sampling frequency was set at 20 Hz. The patients were asked to stand on the platform for 60 seconds in a neutral position with the feet forming a 30-degree angle. The test was carried out 30 seconds with the eyes open and 30 seconds with the eyes closed. All data were analysed using ProKin 36 software to calculate the centre of pressure (CoP) sway on the X (anterior-posterior) and Y (medio-lateral) axes (mm), the CoP velocity on the X (anterior-posterior) and Y (medio-lateral) axes (mm/s), the sway path perimeter (mm), and the area of the ellipse (mm^2). Lower values reflect greater control in maintaining static balance. We considered as primary outcome the reduction of the length of adaptive movements of the following variables:

- SwayAP and SwayML (mm): standard deviation of CoP time series along the anterior-posterior and medio-lateral axes;
- VelocityAP and VelocityML (mm/s): velocity of oscillations along the anterior-posterior and medio-lateral axes;
- Perimeter (mm): total length of CoP trajectory;
- Area (mm^2): area of the 95 % confidence ellipse [11].
- $Romberg_{Area}$: ratio between the value of the area with the eyes closed and with the eyes open.

2.3. Dynamic Balance

Dynamic balance was evaluated using the Tinetti, the Berg Balance scale (BBS) and the Short Physical Performance Battery (SPPB).

- The Tinetti scale is a 16-item standardized screening modality for gait and balance disorders in elderly patients and patients with PD. The scoring system ranges from 0 to 28. The higher the score, the lower the risk of falls [12].
- The BBS is a 14-item scale used to test patients with balance problems, validated in PD. The score ranges from 0 to 56 and does not include gait assessment. The lower the score, the greater the risk of falling [13].
- The SPPB is used to assess functional mobility in elderly patients or individuals affected by neurological diseases. It includes 3 subsets (walking, sit-to-stand and balance). The score ranges from 0 to 12; the lower the score, the lower the functional ability [14].

The study was carried out according to the Declaration of Helsinki and the protocol was approved by the Ethics Committee of the Policlinico Gemelli Foundation (UCSC prot. N 5492/14, 05.03.2014). All patients provided their informed consent prior to inclusion in the study.

2.4. Statistical Analysis

Per-protocol analysis was carried on. Statistical analyses were performed using Statistic Package for Social Sciences (SPSS) version 25.0. Data for categorial variables were expressed as absolute numbers and percentage and the Fisher exact or Pearson's chi-square tests were used to compare them. Continuous variables were expressed as mean, standard deviation (SD) and minimum and maximum value, due to the small sample size. These data were compared using the Mann-Whitney U test. The Pearson correlation coefficient was used to explore the associations between continuous variables. Linear and logistic regression model analysis were performed to provide an adjusted assessment of factors potentially associated with the presence of scoliosis in patients with PD.

3. Results

A total of 16 patients affected by PD were assessed for presence of scoliosis (8 males and 8 females). Half of them met the criteria for scoliosis [3] and were classified as the “true scoliosis” group (TS); the other half presented a Cobb’s angle of less than 10° and were defined as the “non-scoliosis”

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group (NS). Table 1 summarizes the clinical and demographic characteristics of the patients. Besides the proportion of males and females, there was no statistically significant difference between groups in all the examined variables.

Table 1. Clinical and demographic characteristics of the patients and evaluation of cervical pain.

	Non-Scoliosis (N = 8; 50%) Mean ± SD (min - max)	True Scoliosis (N = 8; 50%) Mean ± SD (min - max)	P value
Sex (male/female)	6/2	2/6	0.13 [a]
Age (years)	70.63 ± 10.20 (55 – 82)	70.25 ± 10.87 (53 – 81)	0.94 [b]
BMI (kg/m²)	26.00 ± 2.90 (23 – 31)	25.16 ± 3.75 (21 – 32)	0.62 [b]
Length of disease (months)	66.00 ± 32.14 (20 – 112)	76.00 ± 75.26 (28 – 232)	0.75 [b]
UPDRS score	20.25 ± 6.20 (9 – 28)	24.43 ± 13.39 (9 – 44)	0.47 [b]
H & Y classification	1.69 ± 0.26 (1.50 – 2.00)	1.929 ± 0.70 (1.50 – 3.00)	0.36 [b]
LEDD (mg/day)	456.25 ± 247.04 (100 – 800)	450.00 ± 386.22 (0 – 1000)	0.97 [b]
Number of drugs	2.38 ± 1.06 (1 – 4)	2.14 ± 1.06 (1 – 4)	0.68 [b]
VAS $_{cervical}$	2.50 ± 3.50 (0 – 8)	3.75 ± 4.02 (0 – 8)	0.52[b]
McGill $_{cervical}$	6.88 ± 9.70 (0 – 21)	8.88 ± 10.43 (0 – 26)	0.69[b]

Abbreviations: BMI – Body Mass Index; UPDRS – Unified Parkinson's Disease Rating Scale; MMS – Mini Mental Status; UPDRS- Unified Parkinson's Disease Rating Scale; LEDD – Levodopa Equivalent Daily Dose. [a] *Fischer Test;* [b] *T-student Test.*

The NS group presented a thoracic spinal deviation below the cutoff angle for diagnosing scoliosis. In one case we found a significant dorsal kyphosis (55°) and in another case a grade I retrolisthesis of T2 over L2.

In the TS group, except for one patient who presented a severe scoliosis (50.15°), all the other patients presented a mild form scoliosis with a Cobb's angle ≤ 20°. In most cases the curvature was lumbar and broad range. Other spinal abnormalities observed included one case of listhesis and two cases of vertebral fracture. Details about the radiological characteristics of the patients are displayed.

Static balance evaluation did not show a statistically significant difference between the TS group and the NS group, in all the stabilometric parameters examined. Likewise, dynamic balance evaluation did not show a statistically significant difference in both the SPPB, Tinetti and the Berg Balance scales between groups (Table 2).

Table 2. Clinical evaluation of static and dynamic balance.

	Non-Scoliosis (N = 8) Mean ± SD (min - max)	True Scoliosis (N = 8) Mean ± SD (min - max)	P value
SPPB $_{Equilibrium}$	3.13 ± 0.64 (2 – 4)	3.00 ± 1.00 (2 – 4)	0.78[b]
SPPB $_{Gait}$	4.00 ± 0.00 (4 – 4)	3.43 ± 0.78 (2 – 4)	0.10[b]
SPPB $_{Sit\text{-}to\text{-}stand}$	3.13 ± 0.64 (2 – 4)	2.43 ± 1.51 (0 – 4)	0.29[b]
SPPB $_{Total}$	10.25 ± 1.03 (9 – 12)	8.86 ± 3.02 (5 – 12)	0.28[b]

Tinetti	24.13 ± 1.12 (22 – 26)	21.14 ± 4.18 (12 – 24)	0.11[b]
BBS	47.00 ± 1.60 (45 – 50)	45.29 ± 5.09 (37 – 52)	0.42[b]
	Eyes Open		
Sway AP (mm)	3.13 ± 1.24 (1 – 4)	3.50 ± 1.60 (2 – 6)	0.61[b]
Sway ML (mm)	2.38 ± 1.50 (1 – 6)	3.00 ± 1.77 (1 – 7)	0.46[b]
Velocity AP (mm/s)	9.25 ± 5.82 (3 – 18)	7.38 ± 2.82 (4 – 13)	0.43[b]
Velocity ML (mm/s)	5.25 ± 1.75 (3 – 7)	4.87 ± 1.53 (3 – 7)	0.65[b]
Perimeter (mm)	279.88 ± 143.61 (114 – 496)	237.50 ± 74.91 (158 – 387)	0.45[b]
Area (mm^2)	145.75 ± 108.42 (32 – 383)	183.25 ± 150.85 (59 – 490)	0.58[b]
	Eyes Closed		
Sway AP (mm)	5.25 ± 2.60 (1 – 10)	5.50 ± 1.69 (4 – 8)	0.82[b]
Sway ML (mm)	3.25 ± 1.83 (2 – 7)	3.38 ± 1.68 (1 – 6)	0.89[b]
Velocity AP (mm/s)	26.25 ± 28.68 (5 – 94)	17.38 ± 10.48 (7 – 37)	0.43[b]
Velocity ML (mm/s)	9.62 ± 7.02 (4 – 26)	9.13 ± 4.97 (4 – 20)	0.87[b]
Perimeter (mm)	705.38 ± 723.49 (153 – 2411)	509.50 ± 287.25 (196 – 963)	0.49[b]
Area (mm^2)	393.88 ± 433.23 (44 – 1400)	334.75 ± 194.49 (81 – 580)	0.73[b]
	Romberg (EC/EO)		
Perimeter (mm)	2.25 ± 1.24 (1.34 – 4.97)	2.05 ± 0.83 (1.21 – 3.93)	0.73 [b]
Area (mm^2)	2.75 ± 2.75 (1.34 – 9.52)	2.24 ± 1.44 (1.01 – 5.34)	0.65 [b]

[b] T-student Test.

The study of the Pearson coefficient and linear regression models did not show any association between the Cobb's angle and the Tinetti scale, SPPB, BBS or other stabilometric parameters (Table 3).

Table 3. Association between Cobb's angle and the Tinetti scale, SPPB, BBS or other stabilometric parameters.

Cobb's angle	**Univariate Models[1]**			**Multivariate Models[2]**		
	Unstandardized B Coefficients	P-Value	R Square[a]	Unstandardized B Coefficients	P-Value	R Square[b]
SPPB $_{Total}$	-0.39 ± 1.69	0.82	0.01	-0.51 ± 2.21	0.82	0.56
Tinetti	-0.49 ± 1.16	0.68	0.02	0.17 ± 3.15	0.96	0.52
BBS	-0.79 ± 0.94	0.42	0.05	-0.03 ± 1.10	0.98	0.55
Perimeter (EC/EO)	4.68 ± 2.93	0.13	0.15	4.84 ± 2.97	0.15	0.69
Area (EC/EO)	1.55 ± 1.47	0.31	0.07	1.27 ± 1.68	0.48	0.59

[1] Unadjusted model; [2] Adjusted model for age, sex, disease duration, BMI; LEDD (mg/day) and VAS score; [a] R Square for univariate models; [b] R Square for multivariate models.

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Patients with scoliosis showed a lower variability of the perimeter but a higher variability of the area at the Romberg index compared to the SA group.

Frequency of neck pain revealed a prevalence of 37% in the NS group compared to 50% in the TS group. However, a non-statistically significant difference in cervical pain severity was observed between groups in both the VAS and in the McGill scores (Table 1). Subgroup analysis showed that subjects with a disease duration less than 48 months had a higher prevalence of neck pain compared to those with a disease duration longer than 48 months (n=6; 75.0% vs n= 1; 12.5%; P-value >0.05).

The study of the Pearson coefficient and linear regression models showed no association between cervical pain and the Tinetti, SPPB and BBS or other stabilometric parameters (Table 1).

Table 4. Association between cervical pain and the Tinetti scale, SPPB, Berg balance or other stabilometric parameters.

VAS score	**Univariate Models[1]**			**Multivariate Models[2]**		
	Unstandardized B Coefficients	P-Value	R Square[a]	Unstandardized B Coefficients	P-Value	R Square[b]
SPPB Total	0.36 ± 0.43	0.43	0.05	0.25 ± 0.70	0.73	0.40
Tinetti	0.25 ± 0.29	0.41	0.05	0.94 ± 0.83	0.30	0.50
Berg Balance	0.15 ± 0.27	0.59	0.02	0.19 ± 0.33	0.60	0.42
Perimeter (EC/EO)	-1.08 ± 0.92	0.26	0.09	-0.71 ± 1.30	0.60	0.42
Area (EC/EO)	-0.49 ± 0.44	0.28	0.08	-0.39 ± 0.54	0.50	0.44
Mc Gill score	**Univariate Models[1]**			**Multivariate Models[2]**		
	Unstandardized B Coefficients	P-Value	R Square[a]	Unstandardized B Coefficients	P-Value	R Square[b]
SPPB Total	1.11 ± 1.22	0.38	0.06	0.49 ± 2.01	0.81	0.42
Tinetti	0.72 ± 0.84	0.41	0.05	2.34 ± 2.44	0.37	0.49
Berg Balance	0.48 ± 0.76	0.54	0.03	0.45 ± 0.96	0.66	0.43
Perimeter (EC/EO)	-2.78 ± 2.43	0.27	0.09	-2.62 ± 3.68	0.50	0.46
Area (EC/EO)	-1.31 ± 1.17	0.28	0.08	-1.26 ± 1.53	0.44	0.47

Furthermore, patients with neck pain showed a lower variability of the Romberg index (both area and perimeter) than patients without neck pain.

4. Discussion

Postural deformities including scoliosis tend to occur more often in PD than in the general elderly population [2,15]. Scoliosis and abnormal posture can produce any type of joint pain and exacerbate the overall sensory impairment and the risk of falls in PD [15]. Static and dynamic balance normally rely on the sound integration of visual, vestibular, and proprioceptive sensory information within the basal ganglia and on a coordinated reflex and motor activity [16]. Many studies have demonstrated that patients with PD have subnormal integration of peripheral sensory stimuli with greater reliance on the visual input during static and dynamic motor tasks [3,16]. Furthermore, the development of balance problems and falls is typically indicative of disease progression and worse prognosis [17]. In our study, static and dynamic balance evaluation did not reveal significant differences between the TS and the NS group.

The regression models highlighted that the demographic and clinical characteristics of the patients can significantly influence the dynamic balance assessment questionnaires, but this evidence does not translate into worse stabilometric data in those who had a greater Cobb angle. This could indicate that scoliosis, neck pain and postural imbalance do not have a linear association between them. The severity of PD and the severity of scoliosis are able to influence dynamic imbalance and risk of falling, but this association still needs to be further studied to identify whether the two conditions together determine an increased risk compared to these two risk factors considered individually.

The literature does not provide any data regarding a possible correlation between scoliosis and balance problems in PD so that the only comparison can be done with individuals with idiopathic scoliosis and no PD. In this regard, previous studies have shown a significant correlation between scoliosis and static imbalance in adolescents with moderate idiopathic scoliosis compared to the healthy controls [18,19]. Furthermore, patients with high major curves had a better postural stability than those with low major curves [20]. Regarding the correlation between scoliosis and dynamic imbalance, compared to healthy controls, Shirado et al. [21] found a significant lower weight's shift in the patients with idiopathic scoliosis during both slow and fast side-shifts. Furthermore, weight's shift was less on the concave side than on the convex one. Another study by Haber et al. [22] suggests that scoliotic subjects have a slower speed of gait due to a shorter stride length and a longer stride time. Moreover, they display variations in the timing of muscle activation. Also in this case, to the best of our knowledge, no study investigated the correlation between scoliosis and walking problems in PD. This correlation should be further explored in future studies.

Literature data on neck pain prevalence are currently insufficient both in PD patients and in individuals with idiopathic scoliosis. The study of Kim et al. [23] is the only one reporting a prevalence of neck pain of 5.5% in a cohort of 400 patients with PD, while the study of Topalis et al. [6] is the only one reporting a prevalence of cervical pain of 42% in adults with idiopathic scoliosis. In our study the prevalence of cervical pain was of 50% in PD patients with scoliosis and 37% in those without scoliosis. Regarding the severity of cervical pain, the average VAS and McGill score was tendentially higher in the TS group compared to the NS group. However, this data did not reach a statistical significance. In contrast, subgroup analysis stratified by disease duration showed that individuals with a disease duration >48 months seem to experience less cervical pain compared to patients with more recent onset of the disease. This data is in contrast with the study of Silverdale et al. [24] in which disease duration was not found to influence pain severity in a cohort of 1957 participants with early/moderate PD. Regarding the correlation between neck pain and balance problems, subjects with neck pain did not reveal any difference in dynamic and static balance parameters compared to those without it. Like for scoliosis and neck pain, also in this case we did not find any literature data that investigated this kind of relationship in PD patients. However, if we look at the general population, a study of Ruhe et al. [8] suggests that individuals with neck pain display diminished proprioception and impaired postural control.

Limitations of the Study

This study has a few limitations that should be noted. First, the small sample size and the lack of a control group without PD limit the power of our observation. Second, we performed the clinical assessment at the "ON" phase which could have masked the real level of functional disability and pain of the patients. Third, we did not assess the duration of cervical pain in the group of patients who reported it which could have been useful to make further correlations with balance impairment.

5. Conclusions

Scoliosis, cervical pain and postural imbalance are significant yet often overlooked complaints of PD. Early detection and accurate screening could minimize potential pain and suffering and increase the quality of life. Our results did not show a clear correlation between scoliosis, cervical pain, and static and dynamic imbalance in PD. However, disease duration <48 months seems to be a risk factor for cervical pain. Given the limitations of our study and the paucity of the literature on this subject, further studies are needed to clarify these preliminary findings.

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Informed Consent Statement: All patients provided written informed consent prior to inclusion in the study.

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References

1. Ashour R, Jankovic J. Joint and skeletal deformities in Parkinson's disease, multiple system atrophy, and progressive supranuclear palsy. Movement Disorders 2006; 21: 1856–1863.
2. Alwardat M, Schirinzi T, Di Lazzaro G, et al. The effect of postural deformities on back function and pain in patients with Parkinson's disease. NeuroRehabilitation 2019; 44: 419–424.
3. Doherty KM, van de Warrenburg BP, Peralta MC, et al. Postural deformities in Parkinson's disease. The Lancet Neurology 2011; 10: 538–549.
4. Baik JS, Kim JY, Park JH, et al. Scoliosis in Patients with Parkinson's Disease. Journal of Clinical Neurology 2009; 5: 91.
5. Moon BJ, Smith JS, Ames CP, et al. Prevalence and type of cervical deformities among adults with Parkinson's disease: a cross-sectional study. Journal of Neurosurgery: Spine 2016; 24: 527–534.
6. Topalis C, Grauers A, Diarbakerli E, et al. Neck and back problems in adults with idiopathic scoliosis diagnosed in youth: an observational study of prevalence, change over a mean four year time period and comparison with a control group. Scoliosis and Spinal Disorders; 12. Epub ahead of print June 8, 2017. DOI: 10.1186/s13013-017-0125-z.
7. Shin YJ, Kim WH, Kim SG. Correlations among visual analogue scale, neck disability index, shoulder joint range of motion, and muscle strength in young women with forward head posture. Journal of Exercise Rehabilitation 2017; 13: 413–417.
8. Ruhe A, Fejer R, Walker B. Altered postural sway in patients suffering from non-specific neck pain and whiplash associated disorder - A systematic review of the literature. Chiropractic & Manual Therapies; 19. Epub ahead of print May 24, 2011. DOI: 10.1186/2045-709x-19-13.
9. Casale R, Hansson P. The analgesic effect of localized vibration: a systematic review. Part 1: the neurophysiological basis. European Journal of Physical and Rehabilitation Medicine; 58. Epub ahead of print April 2022. DOI: 10.23736/s1973-9087.22.07415-9.
10. Ferrara PE, Gatto DM, Codazza S, et al. Effects of Focal Muscle Vibration on Gait and Balance in Parkinson Patients: Preliminary Results. Applied Sciences 2022; 12: 10486.
11. Oliveira LF, Simpson DM, Nadal J. Calculation of area of stabilometric signals using principal component analysis. Physiological Measurement 1996; 17: 305–312.
12. Tinetti ME. Performance-Oriented Assessment of Mobility Problems in Elderly Patients. Journal of the American Geriatrics Society 1986; 34: 119–126.
13. Berg K, Wood-Dauphinee S, Williams JI, Maki, B: Measuring balance in the elderly: Validation of an instrument. Can. J. Pub. Health, July/August supplement 2:S7-11, 1992.
14. Cassidy B, Arena S. The Short Physical Performance Battery as a Predictor of Functional Decline. Home Healthcare Now 2022; 40: 168–169.
15. Rabin ML, Earnhardt MC, Patel A, et al. Postural, Bone, and Joint Disorders in Parkinson's Disease. Movement Disorders Clinical Practice 2016; 3: 538–547
16. Paolucci T, Morone G, Fusco A, et al. Effects of perceptive rehabilitation on balance control in patients with Parkinson's disease. NeuroRehabilitation 2014; 34: 113–120.
17. Rascol O, Payoux P, Ory F, et al. Limitations of current Parkinson's disease therapy. Annals of Neurology 2003; 53: S3–S15.
18. Caţan L, Cerbu S, Amaricai E, et al. Assessment of Static Plantar Pressure, Stabilometry, Vitamin D and Bone Mineral Density in Female Adolescents with Moderate Idiopathic Scoliosis. International Journal of Environmental Research and Public Health 2020; 17: 2167.
19. Lee J-U, Kim M-Y, Kim J. Comparison of static plantar foot pressure between healthy subjects and patients with adolescent idiopathic scoliosis. Toxicology and Environmental Health Sciences 2014; 6: 127–132.
20. Gauchard GC, Lascombes P, Kuhnast M, et al. Influence of Different Types of Progressive Idiopathic Scoliosis on Static and Dynamic Postural Control. Spine 2001; 26: 1052–1058.
21. Shirado O, Ito T, Kaneda K, et al. Kinesiologic analysis of dynamic side-shift in patients with idiopathic scoliosis. Archives of Physical Medicine and Rehabilitation 1995; 76: 621–626.

22. Haber CK, Sacco M. Scoliosis: lower limb asymmetries during the gait cycle. Archives of Physiotherapy; 5. Epub ahead of print July 8, 2015. DOI: 10.1186/s40945-015-0001-1.
23. Kim YE, Lee W, Yun JY, et al. Musculoskeletal problems in Parkinson's disease: Neglected issues. Parkinsonism & Related Disorders 2013; 19: 666–669.
24. Silverdale MA, Kobylecki C, Kass-Iliyya L, et al. A detailed clinical study of pain in 1957 participants with early/moderate Parkinson's disease. Parkinsonism & Related Disorders 2018; 56: 27–32.