A comparison of quantitative parameters of axial posture and spinal mobility between motor subtypes of Parkinson's disease

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Background and purpose – Parkinson's disease (PD) is a heterogeneous neurodegenerative disorder characterized by contradictory clinical outcomes among its several subtypes. The disease can manifest with a tremor-dominant (TD) or a non-tremor-dominant (NTD) phenotype. Although the TD subtype may show a better prognosis, there is limited information on the phenotypic differences regarding the level of axial symptoms. For this reason, in this study it was aimed to make a quantitative comparison of axial posture and spinal mobility between PD with TD and NTD.
Methods – This case-control study was conducted on 94 patients with diagnosed PD. A group diagnosis approach was used in the study, such that the diagnosis of each patient was confirmed, and they were assigned to TD and NTD groups by a neurologist expert on movement disorders. Of the patients with PD, 61 were in the TD group, and 33 were in the NTD group. Spinal mouse was used to measure spinal posture and spinal mobility in both sagittal and frontal planes.
Results – Two groups of 61 patients (25 male + 36 female) with TD-PD (mean age: 64.49±10.37 years) and 33 patients (20 male +13 female) with NTD-PD (mean age: 63.45±9.11 years) were enrolled in the study.

Az axiális testtartás és a gerinc-mobilitás kvantitatív paramétereinek összehasonlítása a Parkinson-kór motoros altípusai között
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Háttér és cél – A Parkinson-kór (PD) heterogén neurodegeneratív betegség, aminek különböző altípusait ellentmondásos klinikai eredmények jellemzik. A betegség megnyilvánulhat tremordomináns (TD) vagy nem tremordomináns (NTD) fenotípussal. Bár a TD altípus jobb prognózist mutathat, a fenotípusos különbségekről az axiális tünetek mértékét illetően korlátozott információ áll rendelkezésre. Ezért ebben a tanulmányban az axiális testtartásnak és a gerincmobilitásnak a TD és NTD PD-altípusok közötti kvantitatív összehasonlítását tűztük ki célul.
Módszerek – Eset-kontrollos vizsgálatunkat 94 diagnosztizált PD-s betegen végeztük. A vizsgálatban csoportdiagnosztikai megközelítést alkalmaztunk: minden egyes beteg diagnózisát megerősítette egy mozgásszervi rendellenességekkel foglalkozó neurológus szakértő, és beosztotta őket TD- vagy NTD-csoportba. 61 PD-s beteg került a TD-csoportba, 33 pedig az NTD-csoportba. SpinalMouse eszközzel megmértük a gerinc tartását és mozgékonyságát a sagittalis és a frontális síkban is.
Eredmények – A vizsgálatba két csoportot vontunk be: 61 TD-PD-s beteget (25 férfi és 36 nő; átlagéletkor: 64,49 ± 10,37 év) és 33 NTD-PD-s beteget (20 férfi és 13 nő; átlagéletkor: 63,45 ± 9,11 év). Nem volt szignifikáns különbség a sagittalis és a frontális

There were no significant differences between the patients with TD and NTD in terms of sagittal and frontal postures (p>0.05). In addition to this, anterior trunk tilt was found to significantly increase as the disease stage advanced in both groups. While the greatest anterior trunk tilt change in the TD-PD group was observed in the 3rd stage, NTD-PD group was in the 2.5th stage. Aside from this, the outcomes of the spinal mobility measurements in the frontal and sagittal planes were similar between the groups (p>0.05).

Conclusion – It is widely acknowledged that many clinical aspects of the TD and NTD forms of PD differ; however, in our study, it was observed that there may be no difference in the axial symptoms of the patients with PD in terms of classification according to tremor dominance.

Keywords: Parkinson's disease, tremor, posture, range of motion, rigidity

testtartás tekintetében (p > 0,05) a TD- és NTD-betegek között. Ezen túlmenően az elülső törzsdőlés mindkét csoportban szignifikánsan növekedett a betegség stádiumának előrehaladtával. Míg a TD-PD csoportban a legnagyobb elülsőtörzsdőlés-változás a 3. stádiumban volt megfigyelhető, addig az NTD-PD csoportban a 2,5. stádiumban. Ettől eltekintve a frontális és sagittalis síkban végzett gerincmozgékonysági mérések eredményei hasonlóak voltak a csoportok között (p > 0,05).

Következtetés – Széles körben elismert, hogy a PD TD- és NTD-formáinak számos klinikai aspektusa különbözik; vizsgálatunkban azonban azt figyeltük meg, hogy a PD-s betegek axiális tüneteiben nem feltétlenül van különbség a tremordominancia szerinti besorolás szempontjából.

Kulcsszavak: Parkinson-kór, tremor, testtartás, mozgástartomány, merevség

Parkinson's disease (PD) is the most common movement disorder and the second most common neurodegenerative disease of the central nervous system after Alzheimer's[1]. It is neuropathologically characterized by the presence of Lewy bodies containing α-synuclein in the substantia nigra. Loss of dopaminergic neurons in the pars compacta of the substantia nigra leads to decreased stimulation of voluntary movements and thus the disease progresses with four cardinal motor symptoms that disrupt the normal voluntary movement cycle as bradykinesia, rigidity, tremor and postural instability[2]. Since the trunk forms the basis for body movements and plays an important role in counteracting Parkinson patient's risks to postural control, the consequences of disruption of normal trunk posture due to these motor findings can be challenging for the patient.

Trunk related postural deformities such as scoliosis, severe forward flexion (camptocormia), lateral flexion (pisa syndrome), stooped posture are common in PD which ultimately cause gait abnormalities, activity limitations and balance disorders[3–7]. A significant portion of PD patients may experience one or more trunk related postural deformities; these abnormalities might start off mildly and advance to severe forms in more than 20% of the cases[4]. These are among the most challenging clinical issues in advanced PD which result in a high burden for patients and caregivers by causing physical dependency and injuries[8]. Although studies examining the origins of alterations in trunk posture have typically implicated reduced proprioceptive sense, rigidity, dystonia, myopathy and degenerative changes of the spine, primary etiology is still elusive[4, 5, 9].

It is widely known that patients with PD have restricted spinal flexibility and axial rigidity is largely blamed for this. This is evident in the co-contraction of the hip and trunk muscles, which impairs movement coordination and selectivity and even compromises balance[3]. Adequate trunk range of motion is not only essential for performing daily tasks like bending, twisting, and reaching but also plays a crucial role in stabilizing the body and preventing falls during movement and activities. The finding that trunk flexion, extension and rotations were found to be related with quality of life in patients with PD as a result of the study conducted by *De-la-Cuerda* et al indicates the importance of new studies investigating spinal mobility in this patient group[10].

Patients with PD are affected from the disease progression by marked between-patient variability in clinical phenotype and prognosis, which makes it a highly heterogeneous disease[11]. Different clinical subgroups of PD have been established in the general diagnosis depending on the predominant motor symptom such as tremor (e.g. TD and NTD) and axial signs (postural instability and gait disorder) as the most consistently identified motor subtypes[12]. In comparison to other PD subtypes, it is known that the TD form has a more benign characteristic with a slower disease progression[13]. Research up to date has provided a thorough description of how the trunk related symptoms of patients with PD alter as the disease progresses[3, 4]. Nevertheless, a thorough examination of the existing literature reveals a lack of research directly comparing the axial posture and spinal mobility of PD with TD and NTD phenotypes. For this reason, the

present study aimed to examine axial posture and spinal mobility as defined by axial symptoms at frontal and sagittal plane using a spinal mouse assessment which is a non-invasive and reliable technic in TD versus NTD in patients with PD.

Materials and methods

Study design

The study was designed as a single centre, observational case-controlled study. The study was conducted on patients with idiopathic PD who applied to Health Science University/Gülhane Training and Research Hospital, Department of Neurology, Movement Disorders Clinic between December 2022, and February 2023. The experimental protocol was approved by the Gülhane Scientific Research Ethics Committee (Protocol No: 2022/10) and this study was performed strictly in accordance with the approved guidelines.

Participants

A total of 94 patients with diagnosed PD were recruited to this study. Of the patients, 61 had TD-PD and 33 had NTD-PD. The criteria for inclusion for the participants were (a) diagnosed with idiopathic PD according to the UK Parkinson's Disease Society Brain Bank diagnostic criteria, (b) ability to stand without assistance, hence a modified Hoehn&Yahr stages between 1 to 4. Participants were excluded from the study in case of (a) any neurological problems except PD, (b) any disease or history of surgery that would affect axial functions except PD, (c) any orthopedic disorders of spine that would affect axial functions, (d) scored under 24 in the Turkish version of the revised Mini Mental State Examination[14].

The group assignment was made based on the tremor assessment of a neurologist expert on movement disorders. Criterion for inclusion in the TD-PD group was the presence of rest tremor at any way the motor section in either the head-neck region or in at least one upper or lower extremity. Criterion for inclusion in the NTD-PD group was the presence of no rest tremor in the head-neck region or in any upper extremity[15, 16].

TD-PD refers to patients who initially exhibit tremor accompanied by mild bradykinesia and rigidity. These patients experience slow progression over several years, with tremor remaining the most apparent clinical symptom. Additionally, they may have relatively mild bradykinesia and rigidity, and they may not experience postural instability. NTD-PD was defined as a group that fits to the criteria for idiopathic PD but had tremor in the background[17].

All participants gave written and verbal informed consent to participate in the study. Prior to scheduling their participation, each step of the research was explained verbally, and a study information sheet was given. All participants were informed about the experimental procedure to ensure that they qualified for the study. Participants were allowed to withdraw from the study at any point.

Measurements

The demographic characteristics of the participants (sex, age, height, weight, marital status, educational status), family history, duration of disease diagnosis, side of onset of disease and medications used were questioned and recorded on a standard form. Patients were staged according to the modified Hoehn&Yahr scale by the neurologist[18]. All measurements were performed in the 'on' period of patients.

Axial measurements

Axial posture and spinal mobility were evaluated with SpinalMouse (IDIAG M360, Fehraltorf, Switzerland). Spinal Mouse is an easy-to-apply, non-invasive measuring device that determines the degree of curvature and mobility of the vertebral column in the frontal and sagittal planes[19]. Results were reported segmentally as thoracic, lumbar, and sacral. The patients were asked to take off the clothes above the waist. Before the measurements, the procedure was explained and demonstrated to each participant.

For the posture assessments, the patients were asked to stand in a comfortable standing posture with equal weight bearing on each leg with bare foot. The measurements were completed by moving at a constant speed on the spinous processes previously marked with a cosmetic pen between the C7-S3. Angles of the thoracic kyphosis (T1–2 to T11–12) and lumbar lordosis (T12–L1 to sacrum), position of the sacrum (difference between the sacral angle and the horizontal plane) and anterior trunk tilt (trunk position with relation to the frontal plane) were recorded in degrees **(Figure 1)**. In the frontal plane, if the direction of the curve was correct to the left, it was expressed as negative numbers and vice versa for right curved angles. Thoracic, lumbar, sacral lateral curves and lateral trunk tilt (trunk position with relation to the sagittal plane) were recorded in degrees[5].

Mobility assessments were performed in two positions in sagittal plane (maximum trunk flexion – maximum trunk extension) and in two positions in frontal plane (maximum trunk lateral flexion to both sides). The difference between maximum flexion and maximum extension was recorded as the sagittal mobility and the difference between left and right lateral flexion was recorded as frontal mobility in degrees[5].
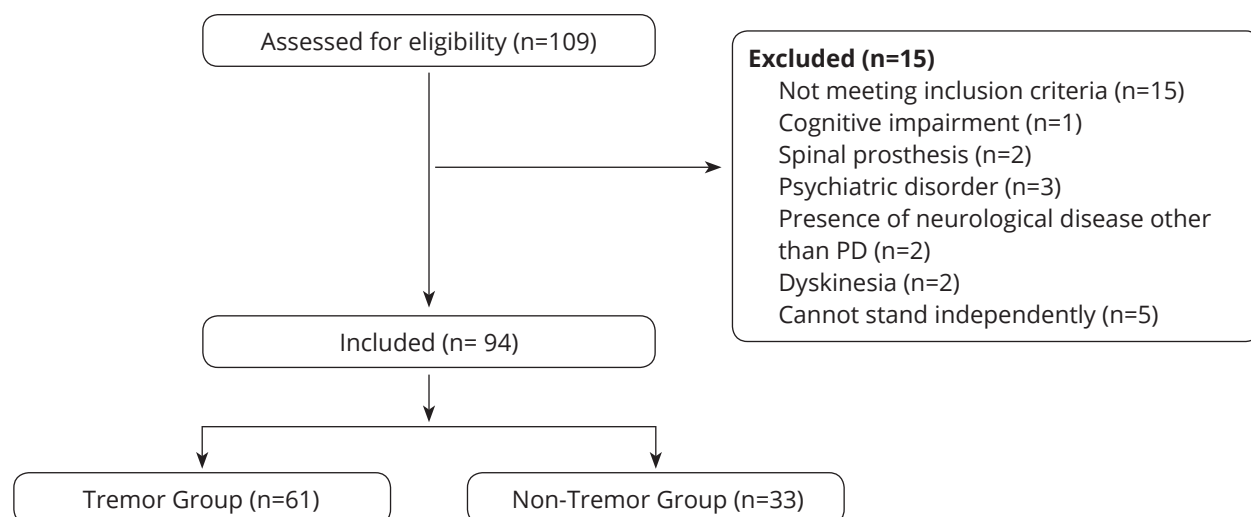
Figure 1. *Flow diagram*

Statistical analysis

Data analysis and calculations were performed using IBM SPSS Statistics 25 (Armonk, NY: IBM Corp.). The Shapiro–Wilks test was used to normality of variables. Descriptive statistics of normally distributed variables were reported as means and standard deviations (mean±SD), and those of non-normally distributed and ordinal variables were presented as median – minimum; maximum [Median (min; max)], interquartile range, and frequency tables. Baseline demographic and physical characteristics of groups were compared using independent sample *t*-tests or Mann-Whitney U tests for numeric variables and the chi-square test for categorical variables. $p<0.05$ was accepted as statistically significant.

A pilot study was conducted to calculate the sample size. Seven patients were included in each group and their data was analysed. G*Power (G*Power, Version 3.1.9.6, Franz Foul, Universität Kiel, German) software program was used for sample size calculation. 28 individuals per group were needed to obtain 90% power with α = 0.05 type I error, an effect size of d = 0.81.

Table 1. *Physical and clinical characteristics of the groups*

Characteristic		Tremor n = 61	Non-tremor n = 33	p
Sex [(male; female), n (%)]		25 (41); 36 (59)	20 (60.6); 13 (39.4)	0.109[a]
Age (year) [Median (min; max)]		65 (34; 82)	62 (46; 80)	0.293[b]
BMI (kg/m^2) [(Mean±SD)]		28.60±3.91	28.86±4.57	0.782[c]
MMSE [Median (min; max)]		28 (24; 30)	28 (24; 30)	0.793[b]
Duration of disease (year) [Median (min; max)]		3 (1; 17)	3(1; 15)	0.914[b]
Dominant side	Right	56 (91.8)	31 (93.9)	0.999[d]
	Left	5 (8.2)	2 (6.1)	
Side of onset n (%)	Right	38 (62.3)	18 (54.5)	0.610[a]
	Left	23 (37.7)	15 (45.5)	
Stages n (%)	1	7 (11.5)	5 (15.2)	0.950[a]
	1.5	19 (31.1)	8 (24.2)	
	2	14 (23)	9 (27.3)	
	2.5	6 (9.8)	4 (12.1)	
	3	12 (19.7)	5 (15.2)	
	4	3 (4.9)	2 (6.1)	

BMI: Body Mass Index, MMSE: Mini Mental State Examination
[a]Continuity Correction Chi-Squared Test, [b]Mann Whitney U test, [c]independent samples T test, [d] Fisher's exact test, SD: standard deviation

Results

During the study, 109 patients diagnosed with PD were interviewed. 15 patients were excluded because they did not meet the inclusion criteria. A total of 94 patients, 61 TD (%65) and 33 NTD (%35) were included in the study **(Figure 1)**. The physical and clinical characteristics of the patients are shown in **Table 1**. The groups were similar in terms of physical and clinical characteristics (p>0.05). There was no difference between the groups in terms of modified Hoehn&Yahr staging.

Table 2. *Comparison of axial posture and spinal mobility in groups*

		Segment	Tremor n = 61	Non-tremor n = 33	p	z/t
Axial posture	Sagittal plane	Thoracic kyphosis (Degrees) (Mean±SD)	47.21±11.81	50.75±12.49	0.186	−1.338[b]
		Lumbal lordosis (Degrees) [Median (IQR)]	−24.08±13.48	−25.33±10.27	0. 643	0.465[a]
		Pelvic tilt (Degrees) (Mean±SD)	14.86±9.57	14.54±7.93	0.869	0.166[b]
		Anterior trunk tilt (Degrees) [Median (IQR)]	7.00 (8.00)	7.00 (7.00)	0.911	−0.111[a]
	Frontal plane	Thoracic lateral tilt (Degrees) [Median (IQR)]	3.50 (4.75)	4.00 (5.50)	0.243	−1.169[a]
		Lumbal lateral tilt (Degrees) (Mean±SD)	−1.73±4.15	−1.66±3.30	0.937	−0.079[b]
		Sacral lateral tilt (Degrees) [Median (IQR)]	3.00 (5.00)	2.00 (3.00)	0.111	−1.592[a]
		Lateral trunk tilt (Degrees) [Median (IQR)]	1.00 (3.00)	2.00 (3.00)	0.865	−0.170[a]
Spinal mobility	Sagittal plane	Thoracic mobility (Degrees) (Mean±SD)	13.16±13.80	12.82±10.18	0.767	0.297[b]
		Lumbal mobility (Degrees) (Mean±SD)	42.08±14.64	47.30±9.59	0.069	−1.843[b]
		Sacral mobility (Degrees) (Mean±SD)	54.26±14.93	55.96±13.20	0.583	−0.550[b]
		Total sagittal mobility (Degrees) (Mean±SD)	92.16±20.52	97.54±14.93	0.188	−1.327[b]
	Frontal plane	Thoracic mobility (Degrees) [Median (IQR)]	29.00 (13.75)	30.00 (9.00)	0.700	−0.386[a]
		Lumbal mobility (Degrees) (Mean±SD)	22.48±8.93	23.03 ±7.87	0.407	−0.832[b]
		Sacral mobility (Degrees) [Median (IQR)]	11.00 (5.50)	12.00 (6.00)	0.369	−0.898[b]
		Total frontal mobility (Degrees) [Median (IQR)]	36.50 (11.75)	40.00 (18.50)	0.160	−1.406[a]

[a]Continuity Correction Chi-Squared Test, [b]Mann Whitney U test, cindependent samples T test, [d]Fisher's exact test, IQR: interquartile range, SD: standard deviation SD: standard deviation

There were no significant differences between the groups in terms of the spinal posture measurements in the sagittal and frontal plane (p>0.05). According to the spinal mobility measurement results, the groups were similar both in the frontal and sagittal planes (p>0.05) **(Table 2)**.

Table 3 and **table 4** summarize the segmental spinal postural advancement in individual groups. Accordingly, anterior trunk tilt was found to significantly increased as the disease stage advanced in both groups. While the greatest anterior trunk tilt change in the TD-PD group was observed in the 3rd stage, in the NTD-PD group it was in the 2.5th stage **(Figure 2)**.

Discussion

According to our knowledge this is the first study which aimed to determine axial posture and segmental spinal mobility differences at frontal and sagittal planes defined as axial symptoms in TD versus NTD patients with PD. As a result of the study, there were no significant differences between TD and NTD groups in terms of segmental spinal posture and mobility. Moreover, as the disease progressed, anterior trunk tilt was observed to increase significantly in both groups. While the greatest anterior trunk tilt change in the TD-PD group was observed in the 3rd stage, in the NTD-PD group it was in the 2.5th stage.

Table 3. *Postural changes based on Hoehn&Yahr staging in tremor group*

	Region	Stage1 n: 7	Stage 1.5 n: 19	Stage 2 n: 14	Stage 2.5 n: 6	Stage 3-4 n: 15	p	χ^2
Sagittal plane	Thoracic kyphosis (Mean±SD)	50.40±4.39	46.55±13.63	49.71±14.05	46.50±7.03	45.52±11.42	0.793	1.690
	Lumbar lordosis (Mean ± SD)	−29.80±10.37	−26.55±15.00	−20.92±14.92	−25.83±7.16	−22.17±13.60	0.770	1.816
	Sacrum position (Mean±SD)	16.60±6.76	14.72±9.83	11.21±10.94	16.00±15.75	17.47±9.48	0.522	3.220
	Anterior trunk tilt (Median (IQR))	5.00 (5.50) (3–4) *	5.00 (5.00) (3–4) *	5.00 (9.50) (3–4) *	8.50 (5.25)	13.00 (9.50) (1/1.5/2) *	*<0.001*	21.696
Frontal plane	Thoracic curvature (Mean±SD)	5.40±2.96	2.83±3.29	5.78±5.22	2.50±4.18	1.17±3.46	0.051	9.596
	Lumbar curvature (Mean±SD)	−4.80±5.35	−1.72±3.56	−3.21±4.26	−0.66±4.26	0.0 ±4.15	0.217	5.768
	Sacral curvature (Median (IQR))	2.00(4.50)	3.00(5.25)	2.00(4.50)	2.50(5.25)	3.00(6.00)	0.959	0.636
	Total lateral curvature (Median (IQR))	0.00±1.22	1.00±1.90	1.42±2.79	3.00±2.00	2.47±4.24	0.228	5.631

IQR: interquartile range, SD: standard deviation
*Difference between stages

This finding indicates that a clinical classification based on tremor dominance may not make any difference in terms of the patients' axial symptoms.

In prognosis studies conducted up to date, it had been reported that TD and NTD subgroups of PD exhibit different clinical features even from the initial moments of diagnosis of the disease[13]. In functional MRI studies, the NTD-PD form showed different intrinsic brain activities compared to TD-PD and healthy subjects[20]. Additionally, a reduction in activation was demonstrated in the prefrontal cortex and globus pallidus[21]. As a matter of fact, in a study conducted by Ren et al., it was reported that NTD-PD patients were more exposed to non-motor symptoms such as cardiovascular symptoms, sleep impairments, mood disturbances, and pain[20]. Nevertheless, it is established that cognitive decline in patients with NTD-PD occurs at a more rapid pace compared to those with TD-PD. Furthermore, the presence of NTD-PD might be regarded as a risk factor for the development of dementia[21]. To our knowledge, this is the first study to investigate the differences in axial symptoms of patients who are classified as a sub-group due to their tremor.

However, in contrast to the previous studies, it was found that tremor being the dominant symptom did not make any difference in terms of axial symptoms.

In one study conducted by *Prodoehl* et al., it was aimed to investigate differences in brain activation between TD and NTD patients with PD[16]. As a result of the comparison, authors reported that patients with NTD-PD had reduced activation in the ipsilateral dorsolateral prefrontal cortex, the globus pallidus interna, and the globus pallidus externa. The observed outcomes remained unexplained by variations in the volume of gray or white matter. On the other hand, *Selikhova* et al. had carried out a systematic review of the case files of 242 donors with pathologically verified PD at the Queen Square Brain Bank for Neurological Disorders. The study revealed a robust correlation between NTD disease pattern and cognitive disability. Furthermore, it was indicated that patients diagnosed with NTD-PD exhibited a notably greater average Lewy body score compared to those diagnosed with TD-PD. More specifically, patients with NTD-PD showed significantly greater number of cortical Lewy bodies in the frontal regions of the brain compared

Table 4. *Postural changes based on Hoehn&Yahr staging in non-tremor group*

	Region	Stage1 n: 5	Stage 1.5 n: 8	Stage 2 n: 9	Stage 2.5 n: 4	Stage 3-4 n: 7	p	χ^2
Sagittal plane	Thoracic kyphosis (Mean±SD)	49.80±5.67	48.00±9.25	47.00±12.43	62.40±10.16	49.85±17.75	0.233	5.575
	Lumbar lordosis (Mean±SD)	−25.80±11.62	−27.00±10.95	−24.62±9.88	−28.60±11.19	−12.71±17.17	0.326	4.640
	Pelvic tilt (Mean±SD)	11.20±9.52	16.25±7.28	13.12±9.68	19.40±5.94	10.71±10.35	0.550	3.045
	Anterior trunk tilt (Median (IQR))	2.80±2.77 (2.5 and 3–4)*	6.62±4.47 (3–4)*	6.50±2.77 (3–4)*	12.80±4.86 (1)*	14.00±6.08 (1/1.5/2)*	*0.003*	15.846
Frontal plane	Thoracic curvature (Mean±SD)	4.00±1.58	4.12±3.39	3.75±3.19	4.60±4.82	3.42±5.02	0.985	0.374
	Lumbar curvature (Median (IQR))	−2.00(6.00)	−1.00(4.75)	−2.00(7.25)	−3.00(5.50)	0.0(2.00)	0.791	1.699
	Sacral curvature (Mean±SD)	2.80±2.38	0.12±1.95	2.25±1.38	2.00±2.00	2.42±2.93	0.239	5.512
	Total lateral curvature (Median (IQR))	2.00(2.50)	1.00(3.50)	1.00(4.50)	1.00(2.50)	4.00(2.00)	0.130	7.105

IQR: interquartile range, SD: Standard deviation
*Difference between stages

to patients with TD-PD. Patients with a TD disease pattern did not live significantly longer than NTD patients and exhibited no difference in mean time to onset of falls and hallucinations[22]. In another systematic review and meta-analysis made by *Cao* et al., the prevalence of axial postural abnormalities and their subtypes in PD were investigated. The results demonstrated that axial postural abnormalities in PD were associated with older age, longer disease duration, a higher H-Y stage, motor fluctuations, and akinetic-rigid subtype[23]. In our study, patients with TD-PD and NTD-PD were compared and no discernible distinction was observed between the two groups. The observed outcome could be attributed to the average disease duration of 3 (ranging from 1 to 17 years) in TD-PD and 3 (ranging from 1 to 15 years) in NTD-PD. This issue remains elusive in the literature. Indeed, the
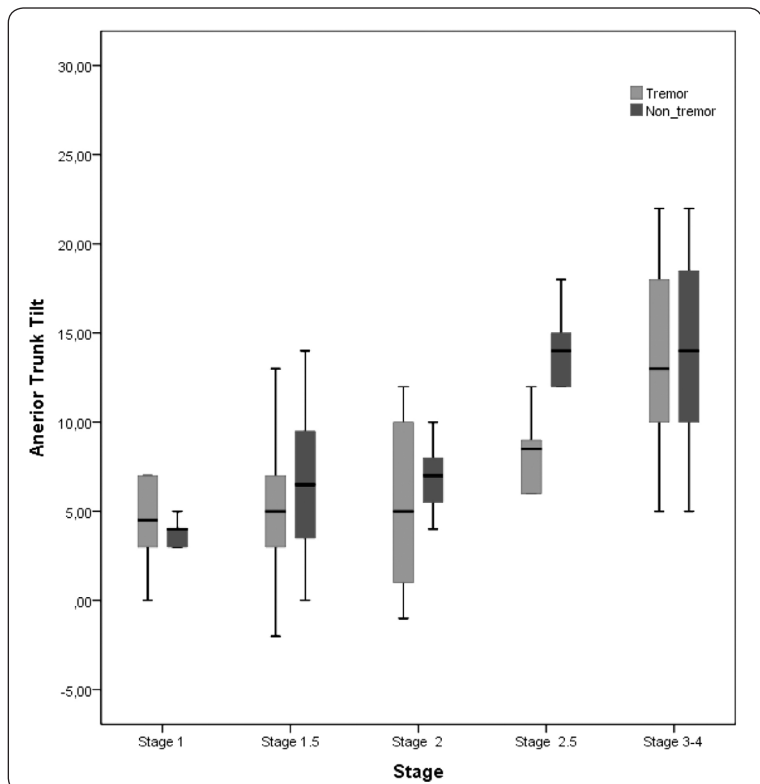

Figure 2. *Anterior Trunk Tilt changes according to disease stages*

available evidence indicates that postural abnormalities are caused by multiple factors and have a complex underlying mechanism[9, 11]. In a study evaluating clinical correlates of anterior and lateral flexion of the thoracolumbar spine and dropped head in patients with PD, the obtained findings clearly indicate that the frequencies of anterior and lateral flexion of the thoracolumbar spine are significantly higher in patients with PD than in controls[24].

As of this moment, research examining postural declines in PD has demonstrated that rigidity in the trunk musculature is a significant factor that may induce spinal posture changes[4]. For instance, an increase in tonus in the front trunk muscles can lead to the upper body to shift forward over the pelvis, resulting in the typical PD posture called stooped posture. The NT-PD sub-form is also called the akinetic-rigid form due to the absence/littleness of tremor but the predominance of symptoms of rigidity and bradykinesia[25]. In this case, it is expected that the deterioration in trunk posture will be greater in patients with the NTD-PD form, where rigidity is more dominant between these two forms[9] and the trunk range of motion will be less[25], but the results of our study do not confirm this hypothesis. The observed phenomenon in our investigation, where NTD-PD patients had low trunk rigidity, may be explained by the fact that the patients included in our study visited our clinic during a specified time period. Moreover, it suggests that the change in posture cannot be attributed to rigidity alone.

Postural abnormalities in patients with PD compared to healthy subjects have been extensively studied in many times in the literature from different perspectives and the results almost lead to a near-consensus. However, there is still a need for more studies specifically comparing postural issues between patients with TD-PD and patients with NTD-PD.

There are some limitations to this study, which could present potential for additional research. One limitation is that it was conducted in a single center. Multicenter studies allow for the expansion of the sample population and the evaluation of the results with a larger sample size. Besides, the cross-sectional design of our study caused the results to be limited to patients who came to our clinic within a certain period. There is a need for further multicenter studies with larger sample sizes to investigate different physical characteristics of the axial structures as well as posture and mobility. Levodopa has been shown to improve postural alignment[26], therefore it is possible that off-period measurements will reveal axial issues more clearly, allowing for more research.

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