The Spine Journal 15 (2015) 115–121

Clinical Study

Coronal plane spinal malalignment and Parkinson's disease: prevalence and associations with disease severity

Hong June Choi, MD[a], Justin S. Smith, MD, PhD[b], Christopher I. Shaffrey, MD[b], Virginie C. Lafage, PhD[c], Frank J. Schwab, MD[c], Christopher P. Ames, MD[d], Morio Matsumoto, MD[e], Jong Sam Baik, MD[f], Yoon Ha, MD[a,*]

[a]*Department of Neurosurgery, College of Medicine, Yonsei University, Seodaemun-gu, Seoul, Korea*
[b]*Department of Neurosurgery, University of Virginia, 914 E Jefferson St., Charlottesville, VA 22902, USA*
[c]*Department of Orthopaedic Surgery, NYU Hospital for Joint Diseases, 333 E 38th St. Fl 4, New York, NY 10016, USA*
[d]*Department of Neurosurgery, University of California San Francisco, 220 Montgomery St., San Francisco, CA 94104, USA*
[e]*Department of Orthopaedic Surgery, School of Medicine, Keio University, 35 Shinanomachi Shinjuku, Tokyo, Japan*
[f]*Department of Neurology, Sanggye Paik Hospital, Inje University College of Medicine, 1342 Dongil-ro, Nowon-gu, Seoul, Korea*

Received 29 January 2014; revised 23 May 2014; accepted 9 July 2014

Abstract

BACKGROUND CONTEXT: Parkinson's disease (PD) is a progressive degenerative disorder of the central nervous system. Patients with PD often present with abnormal posturing.

PURPOSE: To investigate coronal plane deformities in patients with PD, and to evaluate the correlation between clinical features, coronal parameters related to spine alignment, and disease severity.

STUDY DESIGN: A cross-sectional study.

PATIENT SAMPLE: Eighty-nine patients with PD and 89 controls were included.

OUTCOME MEASURES: A medical history was collected from the medical records.

METHODS: This study was a prospective assessment of consecutive patients with PD. Clinical and demographic parameters were collected from medical records and outpatient interviews. Full-length standing anteroposterior and lateral spine radiographs were used to assess the spinal parameters. The threshold for scoliosis was set at a 10° Cobb angle, and the curve type was classified using Schwab classification.

RESULTS: A total of 178 patients (89 in PD and 89 in control groups) were included. Scoliosis was identified in 27 patients (30%) and 22 controls (p=.502). However, coronal imbalance was more common in patients with PD than in controls (11 vs. 0 patients, p=.001). Scoliosis was more common in women than in men (male:female=8:19, p=.04). Back pain was more common in patients with scoliosis than in those without scoliosis (14 of 27 vs. 17 of 62, p=.036). Schwab Type IV (thoracolumbar major) was the most common type of scoliosis in patients with PD and Type V (lumbar major) was the most common type in controls. With adjustment for patient age and gender, multiple linear regression analysis revealed that severity of PD (Unified Parkinson's Disease Rating Scale, p=.037) and magnitude of global coronal malalignment (p=.003) were associated with the scoliosis Cobb angle (p=.037, B=0.139). Direction of scoliosis and side of global coronal malalignment were not significantly correlated with the laterality of predominant PD symptoms (p>.05).

FDA device/drug status: Not applicable.

Author disclosures: ***HJC:*** Nothing to disclose. ***JSS:*** Nothing to disclose. ***CIS:*** Nothing to disclose. ***VCL:*** Nothing to disclose. ***FJS:*** Nothing to disclose. ***CPA:*** Nothing to disclose. ***MM:*** Nothing to disclose. ***JSB:*** Grant: 2012 Inje University research grant (A120254-1201-0000300) (B, Paid directly to institution), the grant of the Korean Health Technology R&D Project, Ministry of Health & Welfare, Republic of Korea (A120254-1201-0000300) (B, Paid directly to institution). ***YH:*** Nothing to disclose.

The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com.

HJC and JSS contributed equally to this work and are considered as co-first authors.

YH and JSB contributed equally to this work as co-corresponding authors.

The authors HJC, MM, JSB, and YH have no personal financial or institutional interests in any of the drugs, materials, or devices described in this article.

This work was supported by the 2012 Inje University research grant and the grant of the Korean Health Technology R&D Project, Ministry of Health & Welfare, Republic of Korea (A120254-1201-0000300).

* Corresponding author. Department of Neurosurgery, Yonsei University College of Medicine, 50 Yonsei-ro, Seodaemun-gu, Seoul 120-752, Korea. Tel.: 82-2-2228-2150; fax: 82-2-393-9979.

E-mail address: yoonhaucsf@gmail.com (Y. Ha)

http://dx.doi.org/10.1016/j.spinee.2014.07.004

CONCLUSIONS: Global coronal malalignment is more prevalent in patients with PD than in controls. Greater severity of PD was significantly associated with greater magnitude of scoliosis Cobb angle, even after adjusting for the effects of patient age and gender. However, direction of scoliosis and side of global coronal malalignment were not significantly associated with the dominant laterality of PD symptoms.

Keywords: Parkinson's disease; Spinal deformity; Sagittal alignment; Pelvic parameters; Pelvic tilt; SVA

Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disorder of the central nervous system. The motor symptoms of PD result from the death of dopamine-generating cells in the substantia nigra of the midbrain. The cause of this cell death is unknown. Patients with PD can present with abnormal posture. An observational study has suggested that up to one-third of patients with PD have a postural deformity [1]. These postural deformities, including camptocormia, antecollis, Pisa syndrome, and scoliosis, can result in difficulties with transfers, gait, ability to live independently at home, and falls [2]. Of the deformities, camptocormia is the most common postural deformity in PD and several studies have focused on camptocormia in PD [1–6]. However, reports on coronal plane deformities such as Pisa syndrome or scoliosis are rare. Some authors have suggested that the laterality of coronal deformity is related to the side of the compromised caudate nucleus in animal models [7–9].

This study prospectively investigated coronal plane deformities in patients with PD and in controls and evaluated for correlations between clinical features, coronal parameters related to spine alignment, and disease severity.

Methods

Patient population and clinical assessment

This study was a prospective assessment of consecutive patients with idiopathic PD presenting to a single academic neurology outpatient clinic over a 12-month period. Inclusion criteria included age more than 21 years and diagnosis of PD based on the United Kingdom Parkinson's Disease Society Brain Bank criteria for PD [10]. Patients were not excluded based on PD severity or on the presence of known spinal disease. Patients with atypical Parkinsonism and those with secondary or drug-induced PD were excluded. Age- ($\pm$1 year) and gender-matched control group was selected from patients with cervical spondylosis without PD. Internal review board approval was obtained for the present study (SPIRB12-078).

A detailed medical history was collected from the medical records. Data extracted included age, sex, duration of PD diagnosis, whether the PD diagnosis was new or whether the diagnosis had been previously established, presenting symptoms, Hoehn and Yahr (H&Y) stage, Unified Parkinson's Disease Rating Scale (UPDRS) score, presence of back pain, and history of L-dopa use.

Radiographic assessment

Global coronal alignment was measured based on full-length standing spine radiographs (anteroposterior views) and was defined as the distance between the C7 plumb line and the central sacral vertical line [11]. Positive or negative coronal alignment occurs when the plumb line falls to the right or left of the central sacral vertical line, respectively (Fig. 1). The C7 sagittal vertical axis (SVA) was measured based on full-length standing spine radiographs (anteroposterior views) and was defined as the distance between the C7 plumb line and the posterosuperior corner of the first sacral vertebra (Fig. 2). The coronal Cobb angle was measured on full-length standing radiographs and was defined as the angle between the line parallel to the superior end plate of the superior-most vertebra of the curve and the line parallel to the inferior end plate of the inferior-most vertebra of the curve (Fig. 1). The Cobb angle threshold for classification of scoliosis was 10° or more. The threshold for classification of coronal imbalance was a magnitude of coronal alignment of 30 mm or more.

Patients with scoliosis were classified based on Schwab curve type classification: Type I (thoracic-only), Type II (upper thoracic major [apex T4–T8]), Type III (lower thoracic major [apex T9–T10]), Type IV (thoracolumbar major [apex T11–L1]), and Type V (lumbar major [L2–L4]) [12].

Statistical analysis

Frequency distributions and summary statistics were calculated for demographic, clinical, and radiographic variables. For categorical variables, cross-tabulations were generated and Fisher exact or Pearson chi-square tests were used to compare distributions. For continuous variables, nonparametric tests were used to investigate the differences between subsets of patients classified by categorical data. Pearson correlation analyses were performed to assess for associations between continuous variables, and multiple linear regression analysis was performed to provide adjusted assessment of factors potentially associated with magnitude of scoliosis Cobb angle. All statistical analyses were performed using SPSS version 18.0 software (SPSS, Inc., Chicago, IL, USA). Values of p less than .05 were considered statistically significant.

Results

Demographic and coronal alignment of patients with PD and controls were summarized in Table 1. A total of 89 patients (41 men and 48 women) with PD and 89 controls were included. Twenty-seven patients in PD (30%; 8 men and 19 women) and 22 patients in control (25%; 6 men and 16 women) groups demonstrated scoliosis (coronal Cobb angle>10°) that were not significantly different (p=.502). However, 11 patients in PD and no patients in the control groups had coronal imbalance (coronal alignment≥30 mm) (p=.001).

Patient characteristics and clinical data for 89 patients with PD stratified based on the presence or absence of scoliosis were summarized in Table 2. Most of those with scoliosis had a Cobb angle between 10° and 20°(n=23); three patients had an angle between 20° and 30° and one patient had an angle more than 30°. Scoliosis was diagnosed more frequently in women than in men (70% vs. 30%; p=.04). The mean age was 67.2 years in the nonscoliosis group and 70.2 years in the scoliosis group (p=.073). The mean time since PD diagnosis was 37.4 months in those with scoliosis and 39.2 months in those without scoliosis (p=.929). In the scoliosis group, 14 patients were newly diagnosed with PD, whereas 13 patients already had an established diagnosis of PD.

There are several characteristic symptoms in patients with PD, of which tremor and rigidity were specifically evaluated for the present study. In patients with scoliosis, 11 were dominant in tremor, 10 were dominant in rigidity, and 6 had mixed symptoms. In patients without scoliosis, 17 were dominant in tremor, 26 were dominant in rigidity, and 19 had mixed symptoms (p=.439; Table 2). The mean H&Y stage/UPDRS scores were 1.82/24.3 and 1.45/21.7 in the scoliosis and nonscoliosis groups, respectively, which were not significantly different (H&Y stage p=.058; UPDRS p=.733; Table 2). In the scoliosis group, 14 (52%) patients had back pain and in the nonscoliosis group, 17 (44%) had back pain (p=.036; Table 2). Twenty patients with scoliosis and 39 patients without scoliosis had a history of L-dopa therapy for PD (p=.593; Table 2).

Coronal imbalance was present in 11 (12.4%) patients (Table 3). Patients with coronal imbalance were significantly older (75.9 vs. 67.1 years, p<.001) and were more likely to have a history of back pain (73% vs. 32%, p=.02). The coronally balanced and imbalanced patient groups did not differ significantly with regard to gender, duration of PD, initial PD symptoms, severity of PD, history of L-dopa treatment, or history of back surgery (p>.05, Table 3).

Among the patients with scoliosis, the patients with coronal imbalance were nine (33.3%), and these patients were significantly older than those with scoliosis and maintenance of coronal alignment (74.0 vs. 68.3 years, p=.019). These two groups did not differ with regard to gender (p=.676), established versus new diagnosis of PD (p=.236), type of initial PD symptoms (tremor, rigidity, or mixed; p=.625), history of back pain (p=.080), history of L-dopa treatment (p=.615), or history of back surgery (p=1.0).

Curve type and coronal balance of scoliosis in PD and control groups were summarized in Table 4. Patients were divided into five scoliosis curve types. The numbers of patients with Types I, II, III, IV, and V were 1, 1, 6, 13, and 6 in PD and 3, 5, 2, 5, and 7 in control groups, respectively (p=.064). Type IV was the most common type in PD and Type V was the most common type in control groups. Direction of scoliosis in PD and control groups was not significantly different (p=.769). In PD group, 14 patients had the direction of scoliosis toward the right and 13 patients had the direction toward the left. In control group, 15 patients had the direction of scoliosis toward the right and 7 patients had the direction toward the left. The mean Cobb angle of scoliosis was 14.4° in PD and 15.2° in control groups (p=.694). The mean magnitude of coronal balance was 23.3 mm in PD and 10.71 mm in control groups (p=.023) (Table 4). There were no statistically significant correlations between the side of dominant PD symptoms and the direction of scoliosis (p=.851) or the side of coronal imbalance (p=.521; Table 5). The mean C7 SVA for

EVIDENCE & METHODS

Context
Parkinson's disease is a progressive neurodegenerative disorder known to be associated with abnormal posturing, especially in more advanced stages. The association of postural changes with the development or worsening of existing coronal plane spinal deformities has not be examined extensively.

Contribution
The authors matched 89 patients with Parkinson's disease to controls on the basis of age and gender. Presence of scoliosis was not significantly different between the two groups but coronal imbalance was more frequently encountered among patients with Parkinson's.

Implications
In this series of patients, global coronal malalignment was more frequently encountered in patients with Parkinson's disease. The results are predicated on the authors' capacity to accurately match patients to controls. While the baseline factors considered (Table 1) may be well controlled for, this does not rule out the possibility of confounding due to variables not assessed in the study. In addition, as a cross-sectional analysis, this investigation may be subject to information (measurement) bias and cannot address changes in patient parameters that may occur over time.

—The Editors

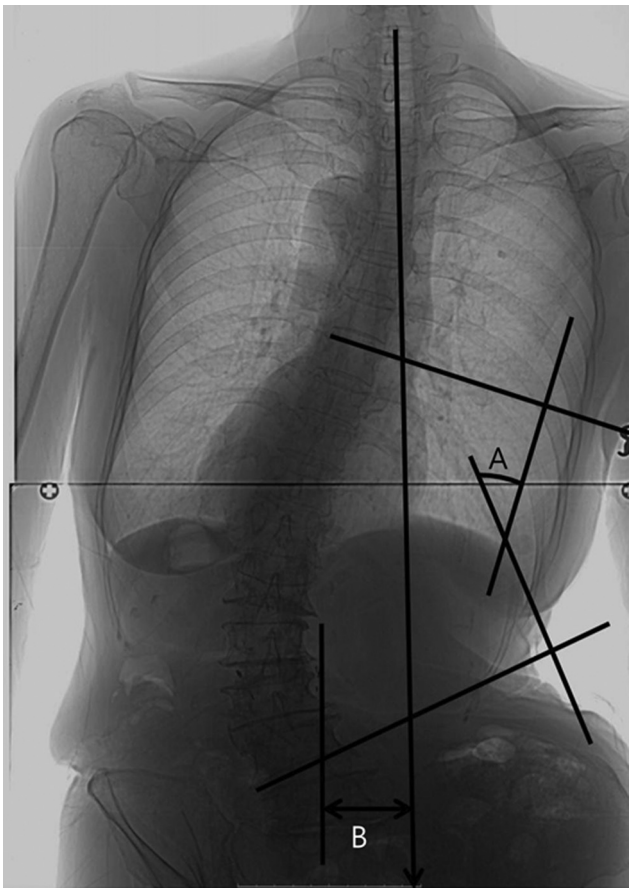

Fig. 1. Parameters on plain X-ray anteroposterior view. (A) Cobb angle; (B) global coronal alignment.

patients with PD with and without scoliosis was 7.7 cm (range=−2 to 18.7 cm) and 4.2 cm (range=−3.6 to 6.3 cm), respectively (p=.013).

Multiple linear regression analysis was performed to assess for factors potentially associated with the magnitude of coronal Cobb angle and coronal balance (Table 6). Five parameters were assessed for Cobb angle (gender, age, UPDRS, C7 SVA, and magnitude of global coronal alignment); six parameters were assessed for coronal balance (gender, age, H&Y stage, duration of PD, Cobb angle, and C7 SVA). The final model with incorporation of all parameters demonstrated a significant overall relationship with scoliosis (R^2=0.379, p=.006) and coronal balance (R^2=0.317, p=.006) (Table 6). In Cobb angle, the unstandardized coefficient for global coronal alignment (mm) was 0.162 (p=.003) and for UPDRS was 0.139 (p=.037). C7 SVA, gender, and age were not significantly associated with the degree of Cobb angle (Table 6). Thus, the severity of PD (based on the UPDRS) was significantly associated with the severity of the scoliosis Cobb angle, even after adjusting for the effects of patient age, gender, global sagittal malalignment (C7 SVA), and the magnitude of global coronal malalignment.

In coronal balance, the unstandardized coefficient for Cobb angle was 1.170 (p=.008, Table 6)

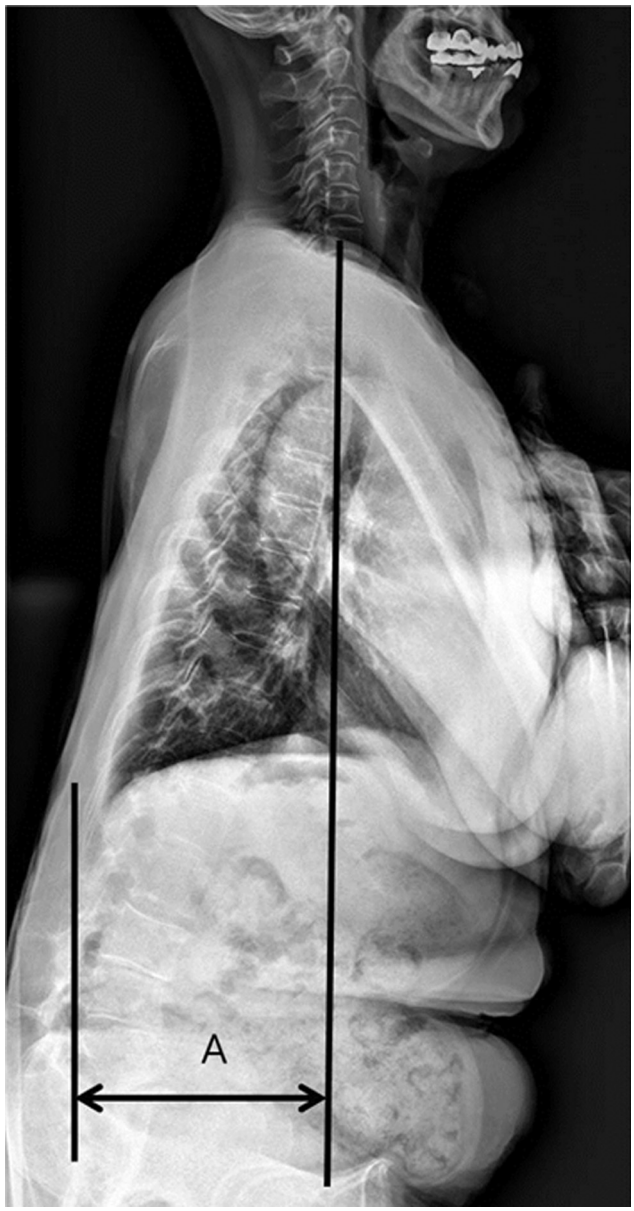

Fig. 2. Parameters on plain X-ray lateral view. (A) Sagittal vertical axis.

Discussion

Several studies have analyzed postural deformities in PD. Many of these studies involved sagittal plane deformities, such as camptocormia, and few studies looked at coronal plane deformities [13–16]. We analyzed the coronal plane in a series of patients with PD and in control group using full-length standing spine radiographs, in addition to clinical characteristics, to assess for the presence of correlations between coronal deformity and clinical characteristics.

In the present study, scoliosis was diagnosed if the Cobb angle was greater than 10°. Twenty-seven patients (30%) with PD were diagnosed with scoliosis according to this definition, and the vast majority of the Cobb angles were

Table 1
Demographic and coronal alignment of patients with PD and the control patients

Demographics	PD	Control	p
Number of patients	89	89	
Gender, M:F (% of F)	41:48 (54)	41:48 (54)	1.000
% of F more than 10°	70	72.73	1.000
Age, y (SD)	68.16 (8.74)	68.11 (8.57)	.966
Age of scoliosis more than 10°, y (mean±SD)	70.25 (9.05)	71.68 (6.24)	.535
Scoliosis≥10° n (% of patients)	27 (30.34)	22 (24.72)	.502
Coronal imbalance≥3 cm n (% of Patients)	11 (12.36)	0	**.001**

PD, Parkinson's disease; M, male; F, female; SD, standard deviation.
Note: Statistically significant p values are shown in bold face type.

between 10° and 30°. Prevalence of scoliosis was not significantly higher in PD than in control groups. However, coronal imbalance of more than 30 mm was significantly associated with PD. As reported above, the prevalence of scoliosis in PD group ranges from 8.4% to 90.5% in both PD & Parkinsonism groups [1,7,8,13,15,17]. However, these prevalence rates reflect clinical observation and lack consistent radiologic confirmation, and therefore, might not accurately represent true scoliosis [4]. Our results should reflect a relatively accurate prevalence, given the use of radiographic criteria.

Spinal deformities, such as scoliosis and kyphosis, are commonly found in elderly patients and are often attributed to the degenerative disease that accompanies the aging process. Given that those with PD have progressive degenerative characteristics and coronal plane deformity that are more common than in the general elderly population [1,7,8,13,15,17], our hypothesis was that age and the duration of PD would correlate with the prevalence of coronal plane deformity. Contrary to our expectation, the duration of PD did not correlate with the prevalence of scoliosis. However, the severity of PD, based on UPDRS scores, was significantly associated with Cobb angle, suggesting that progression of PD may be a risk factor for scoliosis curve progression. Some authors have attempted to explain the conflicting evidence about the relationship between scoliosis and disease duration [1,13]. For example, Ashour and Jankovic [1] found that patients with deformities had higher mean UPDRS scores and were more likely to be treated with L-dopa than patients without a deformity, but there was no significant difference in disease duration between

Table 2
Patient characteristics and clinical data for 89 patients with PD stratified based on the presence or absence of scoliosis

Characteristics and clinial data	Scoliosis (<10°)	Scoliosis (≥10°)	p
Patients, n (%)	62 (70)	27 (30)	
Gender, women (%)	29 (47)	19 (70)	**.04**
Age, y (SD)	67.2 (8.6)	70.2 (9.1)	.073
Duration of PD, mo (SD)	39.2 (31.0)	37.4 (26.7)	.929
Established versus new diagnosis of PD	29:33	14:13	.937
Initial PD symptoms (%)			.439
Tremor	17 (27)	11 (41)	
Rigidity	26 (42)	10 (37)	
Mixed	19 (31)	6 (22)	
H&Y stage (SD)	1.45 (0.55)	1.82 (0.82)	.058
UPDRS (SD)	21.7 (11.1)	24.4 (19.8)	.733
History of back pain (%)	17 (27)	14 (52)	**.036**
History of L-dopa therapy (%)	39 (63)	20 (74)	.593
History of back surgery (%)	5 (8)	5 (19)	.215

SD, standard deviation; PD, Parkinson's disease; H&Y, Hoehn and Yahr; UPDRS, Unified Parkinson's Disease Rating Scale.
Note: Statistically significant p values are shown in bold face type.

Table 3
Patient characteristics and clinical data for 89 patients with PD stratified based on the presence or absence of coronal imbalance

Characteristics based on coronal imbalance	Coronal alignment (<30 mm)	Coronal alignment (≥30 mm)	p
Patients, n (%)	78 (87.6)	11 (12.4)	
Gender, women (%)	40	8	.213
Age, y (SD)	67.1 (8.7)	75.9 (4.1)	.000
Duration of PD, mo (SD)	40.2 (30.0)	28.1 (26.1)	.234
Established versus new diagnosis of PD	39:39	7:4	.524
Initial PD symptoms (%)			.736
Tremor	24 (31)	4 (36)	
Rigidity	31 (40)	5 (46)	
Mixed	23 (29)	2 (18)	
H&Y stage (SD)	1.51 (0.6)	1.86 (0.8)	.177
UPDRS (SD)	21.7 (12.9)	30.1 (24.3)	.485
History of back pain (%)	25 (32)	8 (73)	**.02**
History of L-dopa therapy (%)	53 (68)	6 (55)	.11
History of back surgery (%)	8 (10)	2 (18)	.619

SD, standard deviation; PD, Parkinson's disease; H&Y, Hoehn and Yahr; UPDRS, Unified Parkinson's Disease Rating Scale.
Note: Statistically significant p values are shown in bold face type.

Table 4
Curve type and coronal balance of scoliosis in PD (n=27) and control (n=22) groups

Curve type and coronal balance	PD (n=27)	Control (n=22)	p
Type of scoliosis (%)			.064
I	1 (3.5)	3 (13.6)	
II	1 (3.7)	5 (22.7)	
III	6 (22.2)	2 (9.1)	
IV	13 (48.1)	5 (22.7)	
V	6 (22.2)	7 (31.8)	
Levels involved (SD)	6.77 (2.72)	7.04 (1.93)	.700
Direction of scoliosis (%)			.769
Right	14 (51.9)	15 (68.2)	
Left	13 (48.1)	7 (31.8)	
Cobb angle (°) (SD)	14.46 (5.99)	15.21 (7.27)	.694
Global coronal alignment, mm (SD)	23.36 (24.28)	10.71 (6.81)	**.023**
Direction of global coronal alignment (%)			.082
Right	9 (36.0)	14 (63.6)	
Left	16 (64.0)	8 (36.4)	

PD, Parkinson's disease; SD, standard deviation.
Note: Statistically significant p values are shown in bold face type.

Table 5
Concordance between the dominant side of symptoms and the direction of scoliosis/global coronal malalignment

	Dominant side of symptoms in scoliosis patients		
	Right	Left	p
Direction of scoliosis (N=26)*			.851
Right	9	7	
Left	6	4	
Direction of global coronal malalignment (N=24)†			.521
Right	6	3	
Left	8	7	

* There is one case without dominant symptom side.
† There are three cases without coronal malalignment.

those with and without deformity. Further study of family history or genetic disorders in patients might help clarify the relationship. Some authors have commented that the presence of a family history of similar spinal deformities in non-PD patients with camptocormia/scoliosis or dropped head should raise the possibility of congenital or genetic conditions, such as nemaline myopathy or facioscapulohumeral muscular dystrophy [1]. We believe further analysis of other congenital or genetic conditions might be valuable.

In patients with PD, female gender was a predictor of scoliosis, with a higher prevalence among women than men. However, in the present study, control group also has higher female prevalence. Although the protective role of estrogen in PD has been hypothesized [18–20], there are no reports of a correlation between gender and the prevalence of scoliosis or between gender and other clinical symptoms in patients with PD. There are several hypotheses that women without PD have a higher incidence of adolescent idiopathic/degenerative scoliosis [21–24]. Xu et al. [24] reported that the prevalence of degenerative lumbar scoliosis in the general population was significantly higher among women. This has also been observed in other studies [25–29]. Therefore, further studies should clarify the role of gender to progression of coronal deformity in PD and degenerative coronal plane deformity.

Table 6
Multiple linear regression analysis of the Cobb angle and coronal balance

Variable	Unstandardized coefficient (B)	Standardized coefficient (β)	Significance (p value)
	Cobb angle (°)		
Gender (M=1, F=2)	2.013	0.154	.288
Age, y	0.046	0.065	.684
UPDRS score	0.139	0.339	**.037**
C7 SVA, mm	−0.18	−1.139	.455
Global coronal alignment, mm	0.162	0.485	**.003**
	Coronal balance (mm)		
Gender (M=1, F=2)	−6.163	−0.158	.230
Age, y	0.220	0.100	.483
H&Y stage	2.540	0.097	.470
Duration of PD	−0.091	−0.142	.279
Cobb angle (°)	1.170	0.365	**.008**
C7 SVA, mm	0.086	0.222	.154

M, male; F, female; PD, Parkinson's disease; SVA, sagittal vertical axis; H&Y, Hoehn and Yahr; UPDRS, Unified Parkinson's Disease Rating Scale.
Note: Statistically significant p values are shown in bold face type.

Xu et al. [24] also reported a correlation between bone mineral density (BMD) and degenerative lumbar scoliosis and concluded that osteopenia could contribute to the presence of degenerative lumbar scoliosis. For various reasons, such as reduced mobility, vitamin D deficiency, hyperhomocysteinemia, malnutrition, low body weight, and decreased muscle strength, patients with PD have lower BMD than age-matched controls [30–34]. In this study, we did not measure the BMD, which is one potential limitation in our interpretation of the relationship between variables.

The presence of back pain was significantly higher in patients with scoliosis. Patients are often not aware of any symptoms in the early stages of scoliosis or Pisa syndrome in PD. As the deformity advances, however, pain, dyspnea, and impaired perception of the vertical position can develop [9,35]. The higher prevalence of back pain in patients with scoliosis may not be unexpected, since back pain is one of the common symptoms of scoliosis, even for those without PD [26].

We analyzed the direction of scoliosis and global coronal malalignment and assessed whether these were congruent with the dominant side of PD symptoms. The direction of scoliosis or global coronal malalignment was not associated with the dominant side of PD. Some studies have found that in PD with scoliosis, the trunk usually deviates away from the side of early or predominant symptoms, a finding that was confirmed by animal studies supporting the relationship between decreased striatal dopamine and severity of the scoliosis [7,9,36]. In contrast, other authors found no association between the direction of the curve and the laterality of PD [7–9,13,17,35].

Global sagittal alignment (C7 SVA) did not demonstrate a significant association with the coronal Cobb angle and coronal balance in the present series of patients with PD. Roussouly et al. [37] suggested that, with regard to the relation to scoliotic deformity, it seems that the high prevalence of thoracolumbar kyphosis is a consequence of a combination of lumbar and thoracolumbar scoliosis coupled with disc degeneration in aging. In patients with PD, however, there is no consensus on potential correlations between coronal and sagittal deformities.

This study has limitations. First, this study is a cross-sectional study, limiting our ability to make causal inference from any association between PD and the occurrence of scoliosis. A cohort study would be necessary to determine whether PD is a risk factor for scoliosis. Second, we did not assess for potential impact of coronal plane deformity on health-related quality of life. Third, the number

of study population (89 patients with PD and 89 controls) may not be enough to include full spectrum of PD and coronal plane deformities. Furthermore, lumbar stenosis and associated radiculomyelopathies were not investigated. The number of patients in the present study, although apparently sufficient to appreciate statistically significant differences, is relatively small.

Conclusions

We analyzed patients with PD for coronal plane deformity. Direction of scoliosis and magnitude of global coronal malalignment were not related with laterality of dominant symptoms of PD. The UPDRS was significantly associated with the magnitude of coronal Cobb angle in patients with PD, suggesting that progression of PD may be a risk factor for coronal deformity progression.

References

[1] Ashour R, Jankovic J. Joint and skeletal deformities in Parkinson's disease, multiple system atrophy, and progressive supranuclear palsy. Mov Disord 2006;21:1856–63.

[2] Benatru I, Vaugoyeau M, Azulay JP. Postural disorders in Parkinson's disease. Neurophysiol Clin 2008;38:459–65.

[3] Bloch F, Houeto JL, Tezenas du Montcel S, Bonneville F, Etchepare F, Welter ML, et al. Parkinson's disease with camptocormia. J Neurol Neurosurg Psychiatry 2006;77:1223–8.

[4] Doherty KM, van de Warrenburg BP, Peralta MC, Silveira-Moriyama L, Azulay JP, Gershanik OS, et al. Postural deformities in Parkinson's disease. Lancet Neurol 2011;10:538–49.

[5] Schabitz WR, Glatz K, Schuhan C, Sommer C, Berger C, Schwaninger M, et al. Severe forward flexion of the trunk in Parkinson's disease: focal myopathy of the paraspinal muscles mimicking camptocormia. Mov Disord 2003;18:408–14.

[6] Upadhyaya CD, Starr PA, Mummaneni PV. Spinal deformity and Parkinson's disease: a treatment algorithm. Neurosurg Focus 2010;28:E5.

[7] Duvoisin RC, Marsden CD. Note on the scoliosis of Parkinsonism. J Neurol Neurosurg Psychiatry 1975;38:787–93.

[8] Indo T, Ando K. [Studies on the scoliosis of Parkinsonism (author's transl) In Japanese]. Rinsho Shinkeigaku 1980;20:40–6.

[9] Martin JP. Curvature of the spine in post-encephalitic parkinsonism. J Neurol Neurosurg Psychiatry 1965;28:395–400.

[10] Hughes AJ, Daniel SE, Kilford L, Lees AJ. Accuracy of clinical diagnosis of idiopathic Parkinson's disease: a clinico-pathological study of 100 cases. J Neurol Neurosurg Psychiatry 1992;55:181–4.

[11] O'Brien MF, Kuklo TR, Blanke KM, Lenke LG, eds. Spinal deformity study group radiographic measurement manual. Memphis, TN: Medtronic Sofamor Danek, 2005.

[12] Schwab F, Farcy JP, Bridwell K, Berven S, Glassman S, Harrast J, et al. A clinical impact classification of scoliosis in the adult. Spine 2006;31:2109–14.

[13] Grimes JD, Hassan MN, Trent G, Halle D, Armstrong GW. Clinical and radiographic features of scoliosis in Parkinson's disease. Adv Neurol 1987;45:353–5.

[14] Marsden CD, Duvoisin R. Scoliosis and Parkinson's disease. Arch Neurol 1980;37:253–4.

[15] Serratrice G, Schiano A. [Scoliosis in patients with parkinsonism (In French)]. Nouv Presse Med 1976;5:1834.

[16] Tabamo RE, Fernandez HH, Friedman JH, Lucas PR. Spinal surgery for severe scoliosis in Parkinson's disease. Med Health R I 2000;83:114–5.

[17] Baik JS, Kim JY, Park JH, Han SW, Lee MS. Scoliosis in patients with Parkinson's disease. J Clin Neurol 2009;5:91–4.

[18] Marder K, Tang MX, Alfaro B, Mejia H, Cote L, Jacobs D, et al. Postmenopausal estrogen use and Parkinson's disease with and without dementia. Neurology 1998;50:1141–3.

[19] Saunders-Pullman R, Gordon-Elliott J, Parides M, Fahn S, Saunders HR, Bressman S. The effect of estrogen replacement on early Parkinson's disease. Neurology 1999;52:1417–21.

[20] Shulman LM. Is there a connection between estrogen and Parkinson's disease? Parkinsonism Relat Disord 2002;8:289–95.

[21] Aebi M. The adult scoliosis. Eur Spine J 2005;14:925–48.

[22] Kane WJ, Moe JH. A scoliosis-prevalence survey in Minnesota. Clin Orthop Relat Res 1970;69:216–8.

[23] Kebaish KM, Neubauer PR, Voros GD, Khoshnevisan MA, Skolasky RL. Scoliosis in adults aged forty years and older: prevalence and relationship to age, race, and gender. Spine 2011;36:731–6.

[24] Xu L, Sun X, Huang S, Zhu Z, Qiao J, Zhu F, et al. Degenerative lumbar scoliosis in Chinese Han population: prevalence and relationship to age, gender, bone mineral density, and body mass index. Eur Spine J 2013;22:1326–31.

[25] Bridwell KH, Glassman S, Horton W, Shaffrey C, Schwab F, Zebala LP, et al. Does treatment (nonoperative and operative) improve the two-year quality of life in patients with adult symptomatic lumbar scoliosis: a prospective multicenter evidence-based medicine study. Spine 2009;34:2171–8.

[26] Smith JS, Shaffrey CI, Berven S, Glassman S, Hamill C, Horton W, et al. Improvement of back pain with operative and nonoperative treatment in adults with scoliosis. Neurosurgery 2009;65:86–93; discussion 93–4.

[27] Smith JS, Shaffrey CI, Berven S, Glassman S, Hamill C, Horton W, et al. Operative versus nonoperative treatment of leg pain in adults with scoliosis: a retrospective review of a prospective multicenter database with two-year follow-up. Spine 2009;34:1693–8.

[28] Smith JS, Shaffrey CI, Glassman SD, Berven SH, Schwab FJ, Hamill CL, et al. Risk-benefit assessment of surgery for adult scoliosis: an analysis based on patient age. Spine 2011;36:817–24.

[29] Smith JS, Shaffrey CI, Glassman SD, Carreon LY, Schwab FJ, Lafage V, et al. Clinical and radiographic parameters that distinguish between the best and worst outcomes of scoliosis surgery for adults. Eur Spine J 2013;22:402–10.

[30] Chen YY, Cheng PY, Wu SL, Lai CH. Parkinson's disease and risk of hip fracture: an 8-year follow-up study in Taiwan. Parkinsonism Relat Disord 2012;18:506–9.

[31] Daniel SK, Lansang MC, Okun MS. Bone mineral density (BMD) in male patients with Parkinson's disease. Int J Neurosci 2012;122:523–7.

[32] Gnadinger M, Mellinghoff HU, Kaelin-Lang A. Parkinson's disease and the bones. Swiss Med Wkly 2011;141:w13154.

[33] Jones PD, Stone D, Jones S, Lewis B. Parkinson's disease and bone health. Age Ageing 2010;39:278.

[34] Levin RM, Tucci JR. Parkinson's disease and metabolic bone disorders: a common connection that needs more attention. Endocr Pract 2012;18:591–4.

[35] Di Matteo A, Fasano A, Squintani G, Ricciardi L, Bovi T, Fiaschi A, et al. Lateral trunk flexion in Parkinson's disease: EMG features disclose two different underlying pathophysiological mechanisms. J Neurol 2011;258:740–5.

[36] Herrera-Marschitz M, Utsumi H, Ungerstedt U. Scoliosis in rats with experimentally-induced hemiparkinsonism: dependence upon striatal dopamine denervation. J Neurol Neurosurg Psychiatry 1990;53:39–43.

[37] Roussouly P, Labelle H, Rouissi J, Bodin A. Pre- and post-operative sagittal balance in idiopathic scoliosis: a comparison over the ages of two cohorts of 132 adolescents and 52 adults. Eur Spine J 2013;22 Suppl 2:203–15.