

Analysis of Relationships between Spinal Deformity and Walking Ability in Parkinson's Disease Patients

Yutaka Nakamura¹⁾, Yutaka Machida²⁾, Hiroki Hanawa³⁾, Masayoshi Kanai¹⁾ and Satoshi Asano¹⁾

1) Saitama Spine Center, Higashi-Saitama General Hospital, Saitama, Japan

2) Department of Neurology, Tokyo Rinkai Hospital, Tokyo, Japan

3) Department of Rehabilitation, Higashi-Saitama General Hospital, Saitama, Japan

Abstract:

Introduction: This study aimed to determine impacts on walking ability of spinal deformity and imbalance as distinct from movement disorders in Parkinson's disease (PD).

Methods: Thirty-two patients (15 males, 17 females; mean age 72.5 years) were analyzed. Three, thirteen, eleven, and five were at Hoehn-Yahr stages I, II, III, and IV, respectively. In addition to various spinal imbalance and deformity classifications the following were assessed: Cobb angle (CA) for scoliosis, thoracic kyphosis (TK) at T2-12, thoracolumbar kyphosis (TLK) at T12-L2, lumbar lordosis (LL) at L1-S1, pelvic tilt (PT), pelvic incidence (PI), and sagittal vertical axis (SVA). The Timed Up and Go (TUG) test was used to measure walking ability. Patients were evaluated using the Unified Parkinson's Disease Rating Scale (UPDRS) part III, and bone mineral density (BMD) scans.

Results: Nineteen patients (59%) had spinal deformity and imbalance within the following classifications: thoracic scoliosis, 1; thoracic kyphosis, 2; lumbar scoliosis, 15; Pisa syndrome, 3; camptocormia, 2. Mean values were 20.0° CA for scoliosis, 42.3° TK, 14.8° TLK, 26.7° LL, 20.8° PT, 48.8° PI, and 66.4 mm SVA. The mean TUG score was 13.9s. The UPDRS III mean was 36.6 ± 24.5 points. Mean BMD was 0.856 g/cm² at lumbar L2-4 and 0.585 g/cm² at the femoral neck. UPDRS part III (P<0.001), LL (P<0.05), and femoral neck BMD (P<0.05) significantly correlated to TUG test results.

Conclusions: Distinct from the movement disorders of PD (UPDRS III), loss of normal LL and loss of BMD at the femoral neck were shown to be correlated with diminished walking ability (TUG test) in PD patients. When UPDRS improved in response to L-dopa, walking ability improved. In addition to any PD-specific interventions that contribute to the maintenance of ambulation, interventions specific to the restoration of LL, as well as early treatment for osteoporosis may positively affect HRQOL in PD.

Keywords:

Parkinson's Disease, spinal deformity, walking ability, osteoporosis

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Introduction

Parkinson's disease (PD) is a progressive neurodegenerative condition associated with advancing age, for which management is mostly palliative in the absence of any known curative treatment. The population of PD patients in Japan is increasing with the country's aging demographic, driving a quest to optimize health-related quality of life (HRQOL) in this cohort. It has been reported that musculoskeletal problems are more common in PD patients than in the general population, and it is well known that the preva-

lence of spinal imbalance and deformity are high among PD patients^{1,2)}. Oh et al.²⁾ reported that PD patients had a high prevalence of sagittal spinopelvic malalignment, and that greater PD severity was associated with higher sagittal vertical axis (SVA), a parameter for the amount of forward inclination in posture. The main function of normal lordotic and kyphotic spine segments is to balance the head over the pelvis in an energy-efficient position for ambulation. While maintenance of mobility in daily life is fundamental for HRQOL in PD patients, current pharmacologic and deep brain stimulation treatments³⁾ have had mixed results for

Corresponding author: Yutaka Nakamura, yunaka.nakamura@gmail.com

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postural deformities. Surgical restoration of functional spinopelvic sagittal alignment is known to improve walking ability and, thus, the HRQOL of non-PD patients, but has had high complication and revision rates in PD patients and remains controversial^{4,6}. However, continuing efforts to resolve these issues have recently produced relatively hopeful results in PD patients⁷, thereby raising the need to evaluate the impact potential and clarify the indications for surgical spinal correction adjunctive to treatments targeting neurological conditions. While the relationships between spinal imbalance (including spinal deformity) and walking ability in the general population are well known, to our knowledge few studies have been published on these relationships in PD patients. In addition to staging and movement disorder metrics in PD, we analyzed bone mineral density (BMD) and specific spinal parameters for correlations with walking ability that might help identify interventions with the greatest positive impact potential.

Materials and Methods

Having followed 45 PD patients from December 2005 to June 2018, we excluded 13 patients who were Hoehn-Yahr stage V or could not undertake a standing whole spine X-ray or could not perform the Timed Up and Go (TUG) test for various reasons. Of the 13, one had previously undergone corrective spinal fusion surgery (Case 2) and could not perform the TUG test due to pain. The remaining 32 patients (15 males, 17 females; mean age 72.5 years) were included in this study. The diagnosis of PD was based on the United Kingdom Parkinson's Disease Society Brain Bank Diagnostic Criteria. The Institutional Review Board at our hospital approved the study. Three, thirteen, eleven, and five patients were in Hoehn-Yahr stages I, II, III, and IV, respectively.

The deformities assessed were (1) various spinal imbalance and deformity classifications, (2) Cobb angle (CA) for scoliosis, (3) thoracic kyphosis (TK) at T2-12, (4) thoracolumbar kyphosis (TLK) at T12-L2, (5) lumbar lordosis (LL) at L1-S1, (6) pelvic tilt (PT), (7) pelvic incidence (PI), and (8) SVA. A senior spine surgeon measured the spinal parameters on whole spine X-ray images.

Curves on the coronal plane with CA above 10° and rotation of the vertebra were defined as scoliosis. Thoracic kyphosis was defined as greater than 70 degrees at T2-12. Walking ability was measured by the TUG test, selecting the fastest value among three timed performances wherein the subject rose from a chair, walked 3 m, returned to the chair, and sat back down⁸. If patients used a supporting device such as a cane, this was noted. For patients receiving L-dopa, the TUG test was performed during the ON state. The TUG test is frequently used in the elderly population because it is easy to administer and can generally be completed by older adults. The TUG test cut-off value for predicting the probability for falls in older adults was 13.5s⁹. In addition, we evaluated data from the Unified Parkinson's

Disease Rating Scale (UPDRS) part III, and BMD at lumbar L2-4 and femoral neck. A QDR-4500A Fan Beam X-Ray Bone Densitometer (Hologic) was used to measure BMD. For femoral neck BMD, the lower of the left and right values was used.

Stepwise multiple regression was used to perform statistical analyses. Correlation coefficients with an absolute value of $p < 0.05$ were considered statistically significant. Stat Flex version 6 (Artec Co. Ltd., Osaka, Japan) was used for all statistical analyses.

Results

1. Spinal deformity and imbalance

Overall, 19 of the 32 patients (59%) had spinal deformity and imbalance within the following classifications: thoracic scoliosis, 1; thoracic kyphosis, 2; lumbar scoliosis, 15; Pisa syndrome, 3; and camptocormia, 2. Some patients presented with more than one classification. Mean values were 20.0° CA for scoliosis, 42.3°TK, 14.8°TLK, 26.7°LL, 20.8°PT, 48.8°PI, and 66.4 mm SVA.

2. TUG, UPDRS, and BMD

The mean TUG test score was 13.9 s, and the mean UPDRS part III value was 36.6 ± 24.5 points. Mean BMD was 0.856 g/cm² at lumbar L2-4 and 0.585 g/cm² at the femoral neck (Table 1).

3. Analyses

Thirteen factors submitted as explanatory variable candidates were age, gender, Hoehn-Yahr stage, CA for scoliosis, TK at T2-12, TLK at T12-L2, LL at L1-S1, PT, PI, SVA, UPDRS part III value, BMD at lumbar L2-4 and BMD at the femoral neck. Using stepwise regression, a significance (P value) of 0.15 was determined as the cutoff for inclusion of a variable in the multiple regression equation. The qualifying factors were the UPDRS part III value, LL at L1 - S1, PI, and BMD at the femoral neck. The coefficient of determination was 0.67081, and the multiple correlation coefficient was 0.834456. UPDRS part III (regression coefficient (β)=0.26199 $P < 0.001$, 95% confidence interval (CI) 0.19 to 0.33), LL ($\beta = -0.1208$, $P = 0.0077$. 95% CI -0.204 to -0.04), and femoral neck BMD ($\beta = 19.7871$, $P = 0.0273$. 95% CI 2.82 to 39.75) were found to have significant correlation with TUG test scores (Table 2).

To validate UPDRS III as representative of PD-related movement disorders the scores of all 18 sub-categories were analyzed as explanatory variable candidates using regression analysis against TUG scores as the target variable. Here also, a P value of 0.15 was determined as the cutoff for inclusion in the multiple regression equation. Qualifying factors were finger tapping, hand movement, posture stability, postural tremor of hand, gait, the coefficient of determination was 0.70960, and the multiple correlation coefficient was 0.87510. Of those qualifying factors, hand movement

Table 1. Demographic Data of the 32 PD Patients and Evaluation of Their Radiographic Spinal Parameters.

Age, mean (range), 72.5 (56–85) yr
Gender, M: 15, F: 17
UPDRS, mean (SD), 36.6 (24.4)
Hoehn and Yahr staging scale, stage 1, 3; stage 2, 13; stage 3, 11; stage 4, 5
L-dopa equal amount, mean (SD), 546 (189) mg
PD duration, mean, 8.3 (1-31) yr
Cobb angle (SD) of 15 cases, 20.0 (6.7)
Thoracic kyphosis (SD), 42.3 (18.8)°
Thoracolumbar kyphosis (SD), 14.8 (15.8)°
Lumbar lordosis (SD), 26.7 (21.7)°
Pelvic tilt (SD), 20.8 (10.0)°
Pelvic incidence (SD), 48.8 (11.3)°
Sagittal vertical axis (SD), 66.4 (60.6) mm
Timed Up and Go test (SD), 13.8 (8.2) seconds
Lumbar BMD (SD), 0.856 (0.167) g/cm ²
Femur BMD (SD), 0.585 (0.102) g/cm ²

PD: Parkinson's disease; UPDRS; Unified Parkinson's Disease Rating Scale; BMD; bone mineral density

Table 2. Statistically Significant Variables in the Multiple Logistic Regression Model (n=32, R=0.834456, Adjusted R²=0.67081).

	β	P Value	95%CI
UPDRS part III	0.26199	0.0001	0.19-0.33
LL (lumbar lordosis)	-0.12083	0.0077	-0.204- -0.04
BMD (Femoral neck)	19.7871	0.0273	2.82-39.75
PI (pelvic incidence)	0.15763	0.0582	-0.001-0.3

R: multiple correlation coefficient; R²: coefficient of determination; β : standard partial regression coefficient; CI: confidence interval; UPDRS: Unified Parkinson's Disease Rating Scale; BMD: bone mineral density

(regression coefficient (β)=2.86692, P=0.0018, 95% CI 1.22 to 4.51), and postural tremor of hand (β =1.74652, P=0.0063, 95% CI 0.57 to 2.92) were significantly correlated with TUG test scores. Gait was regression coefficient (β)=1.91380, P=0.1182, 95% CI -0.46 to 4.28.

4. Cases

Case 1 was a 68-year-old female PD patient with severe lumbar kyphotic deformity. She began noticing akinesia in her left hand at 55 years of age. She was diagnosed with PD at another hospital where she was started on L-dopa and maintained at 500 mg. She was introduced to our Department of Neurology at 66 years of age and Hoehn-Yahr stage III. The tremor of her left hand, freezing of gait, and short-stepped gait progressed during follow-up observation, and multiple drugs (sereginin hydrochloride, zonisamide, istradefylline, etc.) were used in combination with 500 mg L-dopa. When measured for this study at 68 years of age, the patient was at 58 points UPDRS part III (gait, 3 (short-stepped); posture, 2 (stooped posture); postural stability, 3) and her three TUG test scores were 15.43, 13.87, and 14.25 s. A compression fracture at T10 and severe kyphosis were

seen in whole spinal radiographs, and her sagittal spinopelvic alignment parameters were 77°TK, 14°LL, 47°PT, 45°PI, and 82 mm SVA. BMD was 0.708 g/cm² at lumbar L2-4 and 0.430 g/cm² at the femoral neck. Although her condition was managed with drugs, her walking ability was declining (Fig. 1).

Case 2 was a 66-year-old female who was referred to our hospital with proximal junctional kyphosis after L2-5PLF performed in two surgeries for spondylolisthesis. She was one of the 13 excluded from the statistical analyses due to her inability to perform the TUG test. She had begun noticing akinesia in her hand at 55 years of age and was diagnosed with PD at another hospital where she was started on L-dopa. Management of her condition using drug therapy was continued by a neurologist for 11 years until her referral to us at Hoehn-Yahr stage III, and with back pain severe enough that she could not perform the TUG test. We performed a two-stage surgery starting with anterior correction at L1-3, followed by T3-Iliac posterior correction that included a posterior column osteotomy at L1/2 and PLIF at L5/S. Postoperatively her LL improved to 31 degrees from -45 degrees pre-op, and her sagittal spinopelvic alignment parameters were 47°TK, 28°PT, 41°PI, and 71 mm SVA (Fig. 2). Moreover, her symptoms disappeared, and she became able to walk, achieving three TUG test scores of 11.25 s, 10.32s, and 9.79s at one year post-op.

Discussion

Many previous studies have demonstrated declines in walking ability and balance associated with aging. In 2011, the AMA published a widely quoted analysis (listing 20 authors) that pooled nine cohort studies and concluded that gait speed was associated with survival in older adults¹⁰. While none of these cohort studies had used the TUG test to

measure gait speed, this test has become widely used worldwide in the evaluation of dynamic balance and ambulatory

capacity in elderly people, as reported in previous studies^{11,12}. In the present study, we clarified three factors that showed correlations with walking ability in PD patients. First, UPDRS part III, which mostly indicates movement disorders characteristic of PD such as resting tremor, akinesia, rigidity, and postural instability, was highly correlated with TUG test scores. Specific UPDRS III sub-categories found to correlate significantly with TUG scores were Hand movement difficulties (akinesia¹³) and Postural Tremor of the Hands. Accordingly, where UPDRS improved in response to L-dopa, walking ability also improved.

Second, in addition to PD-related movement disorders affecting walking disability (TUG test), we clarified a correlation with LL that should be factored in when evaluating treatment options. PD patients characteristically have stooped posture, leaning forward with rounded shoulders, decreased LL, and marked flexion of the hips and knees typical of the forward decompensated sagittal alignment associated with low back pain that affects HRQOL¹⁴. Watanabe et al.¹⁵ reported significantly higher TK, lower LL, and lower PT in PD patients compared with adult spinal deformity patients. Furthermore, global sagittal malalignment progresses without sufficient compensatory mechanisms such as loss of TK and pelvic retroversion. These postural deformities in PD have a multifactorial pathophysiology. Contributing factors include muscular rigidity, axial dystonia, weakness caused by myopathy, body scheme defects through centrally impaired proprioception, and structural changes in the spine¹⁴. In the non-PD population, kyphosis angles are independently associated with decreased mobility, measurable by the TUG test, which is in turn correlated with increased fall risk¹⁶. The present study implicated deterioration of LL as one of the factors for gait impairment in PD patients. The notion of energy-efficient posture is closely related to the

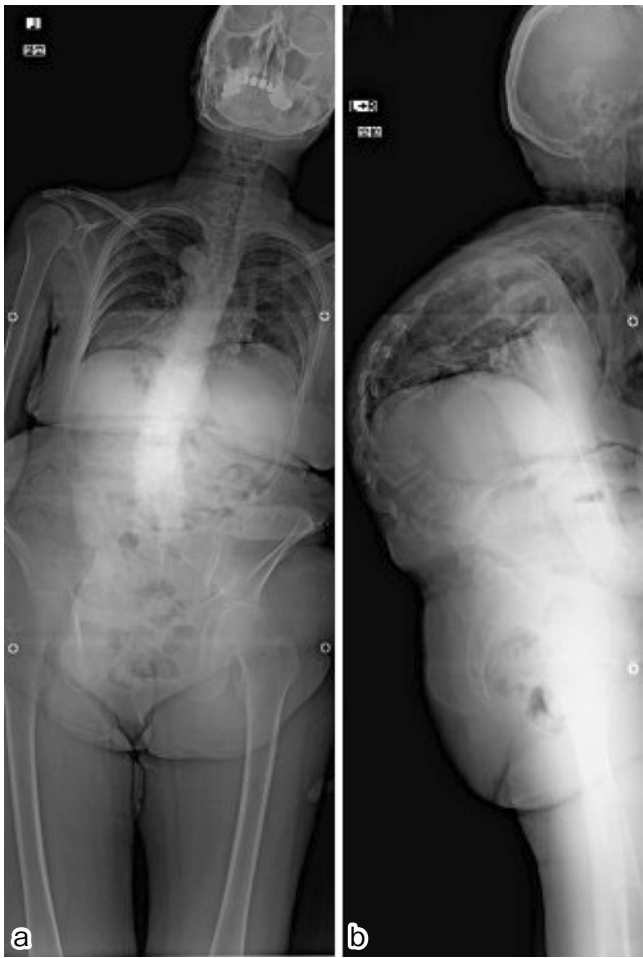


Figure 1. Case 1 (a) Whole spine X-P, anteroposterior view. (b) Whole spine X-P, lateral view.

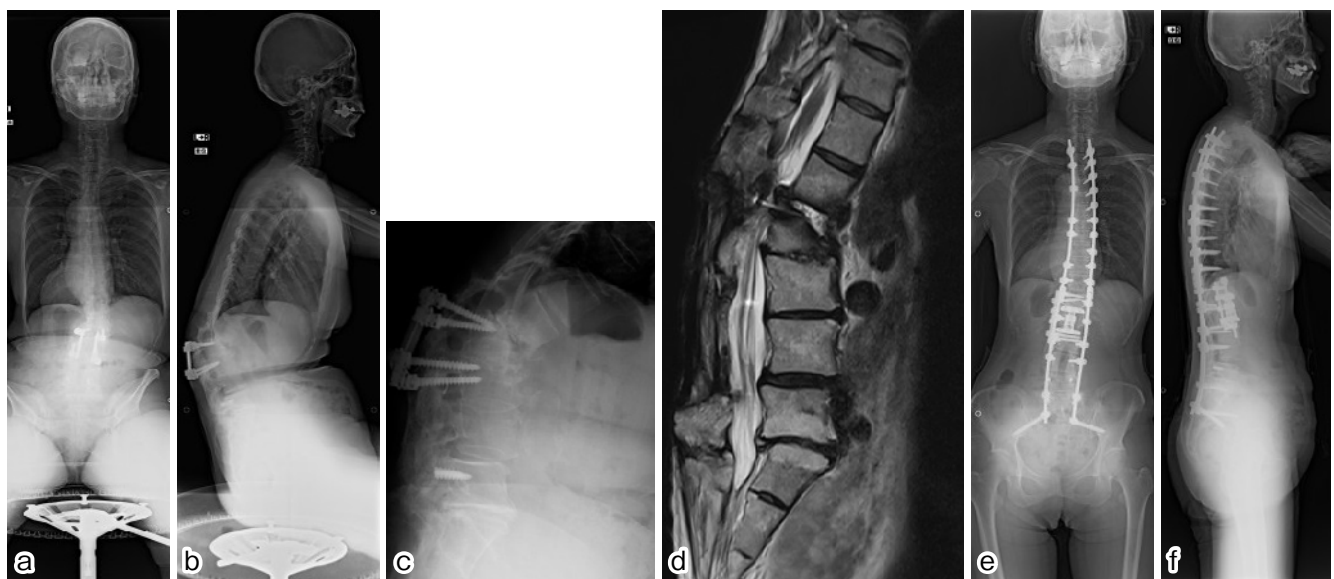


Figure 2. Case 2 (a) Whole spine X-P, anteroposterior view before surgery. (b) Whole spine X-P, lateral view before surgery. (c) lumbar X-P, lateral view before surgery (d) lumbar MRI before surgery. (e) Whole spine X-P, anteroposterior view after surgery. (f) Whole spine X-P, lateral view after surgery.

“cone of economy” concept introduced by Dubouset¹⁷). If the center of gravity falls outside the cone, energy consumption rises, or the person must seek additional support. The larger the deviation is, the more energy is required to maintain balance. For energy conservation when walking or standing, the body tends to right itself by recruiting the low back, buttock, and posterior thigh muscles to tilt the pelvis. Fatigue, aching, and pain may be experienced in these muscles along with secondary musculoskeletal complications, including hip flexion contracture that can result from shortening of the anterior hip flexor muscles with chronic overuse. Subsequently, a decrease in the strength of these muscles can result in loss of ambulatory capacity, exacerbating secondary musculoskeletal complications further, including BMD loss. Numerous studies have suggested that the typical myopathic changes observed in PD patients are related to disuse or denervation secondary to severe primary postural abnormalities¹²). Initially, physical therapy for a flat back to strengthen the gluteal, low back, abdominal, and hamstring muscles should focus on the prevention of these secondary musculoskeletal complications^{18,19}). Hongo et al.²⁰) reported that back muscle exercises can improve LL in osteoporotic patients, and numerous studies^{14,19,21}) have suggested this to be true in the earlier stages of PD. Although surgical interventions have had high complication and revision rates in PD patients^{4,6}), the progression of comorbidities without such treatment may outweigh the surgical risks if conservative methods fail, and when pain leads to immobilization. Recently, Bourghi et al.⁷) reported relatively good results of surgical treatment in a small series of PD patients through improvement of LL by spinal correction with long fusion. Our data suggested that well controlled drug-therapy by a neurologist is prerequisite to long fusion surgery for PD patients. This is just one case but the mobility improvement seen in Case 2 above illustrates the distinctness of the spinal alignment factors from movement disorder factors in PD patient mobility. Although causality was not clarified, walking ability can serve as a clinical indicator of well-being among older adults in general, and PD patients with spinal deformity and sagittal malalignment who are highly motivated to walk may need to consider corrective long fusion to forestall the vicious cycle of immobilization and de-conditioning.

The third correlative factor in this study was decreased BMD at the femoral neck.

Incidence of hip fracture among PD patients is high²²). In a systematic review, Kelli²³) reported that PD patients are at high risk for both osteoporosis and osteopenia compared with healthy controls. F. van reported that the causation of bone loss in PD is multifactorial, and includes immobility, decreased muscle strength, low body weight, Vitamin D deficiency, and hyperhomocysteinaemia, etc. Most of these affect or reinforce each other^{1,24}). In this study, a statistically significant relationship was found between decreased BMD of the femoral neck and TUG test results. This could be partially explained by the relatively long duration from onset (PD duration: mean, 8.3yr) among the patients in this study,

and this explanation would be consistent with the proposition that immobilization is one of several causal factors. The risk of sustaining osteoporotic fractures is exacerbated by an increased risk of falls in patients with PD. These concomitant risks for femoral neck fractures in PD elevate the clinical importance of BMD loss as a comorbidity that both affects and is affected by walking ability. It follows that more frequent osteoporosis screening should be considered for PD patients, and that therapeutic interventions should be initiated. If osteoporosis is present, we should begin suitable treatment with bisphosphonates and vitamin D supplementation, ensure an adequate intake of calcium, and sometimes use teriparatide or denosumab injections immediately.

Conclusion

Distinct from the movement disorders of PD (UPDRS part III), loss of normal LL and loss of BMD at the femoral neck were shown to be correlated with diminished walking ability (TUG test) in PD patients. Accordingly, in addition to any PD-specific interventions that contribute to the maintenance of ambulation, interventions specific to the restoration of LL, as well as early treatment for osteoporosis may positively affect HRQOL in PD.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Author Contributions: Yutaka Nakamura wrote and prepared the manuscript, and all of the authors participated in the study design. All authors have read, reviewed, and approved the article.

References

1. Kim YE, Lee WW, Yun JY, et al. Musculoskeletal problems in Parkinson's disease: Neglected issues. *Parkinsonism Relat Disord.* 2013;19(7):666-9.
2. Oh JK, Smith JS, Shaffrey CI, et al. Sagittal spinopelvic malalignment in Parkinson disease: prevalence and associations with disease severity. *Spine.* 2014;39(14):E833-41.
3. Hellmann MA, Djaldetti R, Israel Z, et al. Effect of deep brain subthalamic stimulation on camptocormia and postural abnormalities in idiopathic Parkinson's disease. *Mov Disord.* 2006;21(11):2008-10.
4. Koller H, Acosta F, Zenner J, et al. Spinal surgery in patients with Parkinson's disease: experiences with the challenges posed by sagittal imbalance and the Parkinson's spine. *Eur Spine J.* 2010;19(10):1785-94.
5. Babat LB, McLain RF, Bingaman W, et al. Spinal surgery in patients with Parkinson's disease: construct failure and progressive deformity. *Spine.* 2004;29(18):2006-12.
6. Galbusera F, Bassani T, Stucovitz E, et al. Surgical treatment of spinal disorders in Parkinson's disease. *Eur Spine J.* 2018;27(Suppl 1):101-8.
7. Bourghli A, Guérin P, Vital JM, et al. Posterior spinal fusion from T2 to the sacrum for the management of major deformities in patients with Parkinson disease: a retrospective review with analysis of complications. *J Spine Disord Tech.* 2012;25(3):E53-60.

8. Podsiadlo R, Richardson S. The time "Up& Go": A test of basic functional mobility for frail elderly persons. *J AM Geriatr Soc.* 1991;39(2):142-8.
9. Shumway-Cook A, Brauer S, Woollacott M. Predicting the probability for falls in community-dwelling older adults using the timed up & go test. *Phys Ther.* 2000;80(9):896-903.
10. Studenski S, Perera S, Patel K, et al. Gait Speed and survival in older Adults. *JAMA.* 2011;305(1):50-8.
11. Winter DA, Patla AE, Frank JS, et al. Biomechanical walking pattern change in the fit and healthy elderly. *Phys Ther.* 1990;70(6):340-7.
12. Driscoll C, Aubin CE, Labelle H, et al. The relationship between hip flexion/extension and the sagittal curves of the spine. *Stud. Health Technol Inform.* 2008;140:90-5.
13. Martínez-Martín P, Gil-Nagel A, Gracia LM, et al. Unified Parkinson's Disease Rating Scale characteristics and structure. The Co-operative Multicentric Group. *Mov Disord.* 1994;9(1):76-83.
14. Doherty KM, van de Warrenburg BP, Peralta MC, et al. Postural deformities in Parkinson's disease. *Lancet Neurol.* 2011;10(6):538-49.
15. Watanabe K, Hirano T, Katsumi K, et al. Characteristics of spinopelvic alignment in Parkinson's disease: Comparison with adult spinal deformity. *J Orthop Sci.* 2017;22(1):16-21.
16. Katzman WB, Vittinghoff E, Kado DM. Age-related hyperkyphosis, independent of spinal osteoporosis, is associated with impaired mobility in older community-dwelling women. *Osteoporos Int.* 2011;22(1):85-90.
17. Dubousset J. Three-dimensional analysis of the scoliotic deformity, in Weinstein SL (ed): *The Pediatric Spine: Principles and Practice.* New York: Raven Press Ltd; 1994. 479-96p.
18. Keus SHJ, Munneke M, Graziano M, et al. European physiotherapy guideline for Parkinson's disease. the Netherlands: KNGF/PakinsonNet; 2014.
19. Speelman AD, van de Warrenburg BP, van Nimwegen M, et al. How might physical activity benefit patients with Parkinson disease? *Nat Rev Neurol.* 2011;7(9):528-34.
20. Hongo M, Miyakoshi N, Shimada Y. Back extensor strengthening exercise and osteoporosis. *Osteoporosis in Orthopedics: Assessment and Therapeutic Options.* 2016;11:235-52.
21. Earhart GM, Falvo MJ. Parkinson disease and exercise. *Compr Physiol.* 2013;3(2):833-48.
22. Sato Y, Kaji M, Tsuru T, et al. Risk factor for hip fracture among elderly patients with Parkinson's Disease. *J Neuro Sci.* 2001;182:89-93.
23. Torsney KM, Noyce AJ, Doherty KM, et al. Bone health in Parkinson's disease: a systematic review and meta-analysis. *J Neurol Neurosurg Psychiatry.* 2014;85(10):1159-66.
24. van den Bos F, Speelman AD, Samson M, et al. Parkinson's disease and osteoporosis. *Age Ageing.* 2013;42(2):156-62.

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