Original Article

Do Bone Mineral Density, Trabecular Bone Score, and Hip Structural Analysis Differ in Indian Men with Parkinson's Disease? A Case-Control Pilot Study from a Tertiary Center in Southern India

Basavaraj G. Sooragonda, Kalyani Sridharan, Rohit Ninan Benjamin, A. T. Prabhakar[1], Ajith Sivadasan[1], Nitin Kapoor, Kripa Elizabeth Cherian, Felix K. Jebasingh, Sanjith Aaron[1], Vivek Mathew[1], Hesarghatta S. Asha, Nihal Thomas, Thomas V. Paul

Departments of Endocrinology and [1]Neurology, Christian Medical College, Vellore, Tamil Nadu, India

Abstract

Objective: Parkinson's disease (PD) is a neurodegenerative condition that is characterized by bradykinesia, rigidity, and gait instability. Inherent to this condition is an increased predisposition to falls and fractures. Bone health in Parkinson's disease in India has not been studied thus far. This study aimed to assess the bone mineral density (BMD), trabecular bone score (TBS), and hip structural analysis (HSA) in Indian men with PD and compare them with matched controls. **Methodology:** A case-control study done at a tertiary care center from southern India. Bone biochemistry, BMD, TBS, and HSA were assessed. **Results:** Among 40 cases and 40 age, gender, and body mass index (BMI)-matched controls, there was no significant difference in BMD between both groups. The mean (SD) TBS at the lumbar spine [1.349 (0.090)] was significantly ($P = 0.019$) lower in men with PD as compared to matched controls [1.401 (0.089)]. Among the parameters of HSA, the buckling ratios were significantly higher at the femoral neck [11.8 (2.2) vs 9.4 (2.2); $P = 0.001$] and inter-trochanteric region [9.4 (2.1) vs 7.8 (1.4); $P = 0.002$] among cases as compared to matched controls. Vitamin D deficiency was significantly higher in this cohort of patients as was bone turnover marker indicating bone loss and a high bone turnover state. **Conclusion:** A comprehensive bone health assessment comprising BMD, TBS, and HSA may be required to capture all aspects of bone strength in Indian men with PD as BMD assessment as a stand-alone tool may not suffice to obtain all information pertaining to fracture risk in these individuals.

Keywords: Bone mineral density, hip structural analysis, Parkinson's disease, trabecular bone score

Introduction

Parkinson's disease (PD) was initially described by James Parkinson in the nineteenth century as the "shaking palsy" and detailed the major symptoms of the disease.[1] It is characterized by both motor and non-motor symptoms, and osteoporosis is an important non-motor component seen in those affected.

The incidence and prevalence of PD increase with advancing age, being present in about 1% of people over the age of 65 years.[2,3] There is no homogenous and large epidemiological data on PD from India despite there being a large prevalence of PD in India. However, published literature gives prevalence rates which varies from 14.1 to 328 per lakh population.[4,5]

Osteoporosis, a metabolic skeletal disorder characterized by low bone mass and microarchitectural deterioration of bone tissue, may be seen in many of the patients suffering from PD.[6–9] Patients with PD have a higher risk of falls, and the factors that affect the likelihood of falls in these individuals include poor balance, freezing of gait, impaired lower extremity sensation, and weakness coupled with depression.[10–12] The risk increases with increasing severity of the disease. The presence of osteoporosis associated with an excess risk for falls increases the chance of a fracture[13–17] and its related adverse consequences on healthcare costs, morbidity, and heightened mortality.[18,19]

Although there are studies showing the impact of PD on bone mineral density (BMD), most of these studies are from Western countries[6]; data from Asian countries that include the Indian subcontinent are sparse. In addition, the predictive capacity of BMD as a stand-alone measure may not be adequate to capture fracture risk in its entirety.[6] Microarchitectural alterations and geometric changes could also potentially contribute to fracture risk. Trabecular bone score (TBS) is a densitometric tool that evaluates pixel gray-level variations in the lumbar spine dual-energy X-ray absorptiometry (DXA) image, providing an indirect

Address for correspondence: Dr. Kripa Elizabeth Cherian, Department of Endocrinology, Christian Medical College, Vellore - 632 004, Tamil Nadu, India.
E-mail: kripaec@gmail.com

Submitted: 11-Jan-2023 **Revised:** 08-Mar-2023 **Accepted:** 24-Apr-2023
Published: 20-Jul-2023

DOI: 10.4103/aian.aian_29_23

measure of bone microarchitecture.[7] TBS improves fracture risk prediction beyond that which are provided by BMD and clinical risk factors; it can also be incorporated in the fracture risk assessment tool (FRAX) to enhance fracture risk prediction.[8]

Hip structural analysis (HSA) is also performed by the DXA and evaluates variables pertaining to proximal hip geometry such as the cross-sectional area (CSA), cross-sectional moment of inertia (CSMI), section modulus (Z), and buckling ratio (BR).[9,10] Each of these geometric indices is measured at three sites, namely the narrow neck (NN), the inter-trochanteric area (IT), and the femoral shaft (FS),[11,12] and provides information pertaining to the geometric characteristics of the proximal hip which might prove to be relevant in the context of fracture risk.

With limited literature being available on HSA and TBS in men with Parkinsonism, we assessed the DXA-derived parameters that included BMD, TBS, and HSA as well as the bone biochemistry in Indian men with Parkinsonism and compared them with age- and BMI-matched controls, recruited from the community.

Methodology

Subjects

This was a case-control study done between September 1, 2018, and February 29, 2020, at a tertiary care center in southern India. Men in the age group of 50 to 80 years were recruited in the study jointly from the departments of Endocrinology and Neurology. Group 1 included patients with Parkinson's disease (PD) defined as per the Movement Disorder Society (MDS) criteria, with modified Hoen and Yahr stage (modified HY stage) less than ≤4.[20] Group 2 included age, gender, and body mass index (BMI) matched healthy controls from the community. Controls were healthy age and BMI-matched community dwelling men who were otherwise healthy. These were usually the male relatives of patients attending the hospital who were not known to have Parkinson's disease or other secondary conditions that could potentially affect bone health. Their health status was ascertained historically by enquiring whether they had any co-morbid illness and were on regular medication for any disease state.

Patients with secondary osteoporosis including those on chronic oral steroid use, HIV disease, dementia, advanced stages of chronic kidney disease (stage 4 and 5), chronic liver disease, and patients receiving bisphosphonates, calcitonin, or teriparatide were excluded from the study. Dementia was formally assessed by the neurologist using the Montreal Cognitive Assessment Scale. Patients with a score that was less than 26 were excluded and patients with vascular Parkinsonism were also excluded. The study was approved by the institutional review board and ethics committee. Written informed consent was obtained from all subjects enrolled in the study.

Clinical examination

Physical examination was performed in all subjects. Body weight was measured using an electronic scale, and height was measured to the nearest 0.1 cm by using a wall-mounted stadiometer. Subjects were asked to stand straight, relaxed, and in light clothing. BMI was calculated as the ratio of weight(kg)/height(m)^2 (kg/m^2). Waist circumference (WC) was measured at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest, using a stretch-resistant tape. Hip circumference (HC) was measured around the widest portion of the buttocks. Waist–hip ratio (WHR) was calculated as the ratio between WC and HC.

Dual-energy X-ray absorptiometry (DXA) scan parameters

A. Bone mineral density

Areal BMD (g/cm^2) at the non-fractured femoral neck, total hip, and lumbar spine (L1-L4) was assessed using DXA scanner Hologic Machine Discovery A series. DXA uses the principle of dual-energy X-ray absorptiometry in which two X-ray beams of differing energies pass through the body; these are attenuated to different extents by various body tissues such as bone, muscle, and fat. This may be used to study the differential mass and distribution of these tissues.

The categorization of BMD into normal, osteopenia, and osteoporosis was done based on T-scores, as defined by the International Society for Clinical Densitometry (ISCD) guidelines.[20] The coefficient of variation (CV) of BMD assessment at the femoral neck was 0.8% and that at the lumbar spine was 0.7%. The DXA scan was performed by two technicians with more than ten years of experience, and the CV was the average of their independent observations.

B. Trabecular bone score (TBS)

TBS is a non-invasive method that evaluates pixel gray-level variations in the lumbar spine DXA image and helps in assessing the microarchitecture of the bone. TBS was assessed using iNsight Software version 3 (Med-Imaps, Bordeaux, France). A TBS value of more than 1.350 indicates normal microarchitecture. TBS value between 1.200 and 1.350 indicates partially degraded microarchitecture, and a TBS <1.200 indicates degraded bone microarchitecture.[21]

C. Hip structural analysis

Hip structural analysis (HSA) is a simple tool to determine bone strength at the proximal femur by assessment of geometric parameters.[22] The HSA program performs its analysis at three sites of the proximal femur using averages from five parallel lines one pixel apart across the cross section of these sites:

(1) Narrow neck (NN), which is the narrowest point of the femoral neck
(2) Inter-trochanteric region (IT), along the bisector of the angle of the axes of the neck and femoral shaft
(3) Femoral shaft (FS), a site across the shaft at 2 cm distal to the midpoint of the lesser trochanter.

The following four parameters of HSA were assessed in all the three sites:

a. Cross-sectional area (CSA) excluding soft spaces in the marrow and pores—an index of resistance to axial forces (cm^2).
b. Cross-sectional moment of inertia (CSMI)—estimate of resistance to bending forces in a cross section (cm^4).
c. Section modulus (Z)—an index of strength calculated as the CSMI ÷ the distance from the bone edge to the centroid (assumed here to be half the subperiosteal width) (cm^3).
d. Buckling ratio (BR)—index of susceptibility to local cortical buckling under compressive loads.

The other parameters which may be analyzed using the HSA tool include.

Hip axis length (HAL)—the distance from the pelvic rim to the outer margin of the greater trochanter along the axis of the femoral neck.

Biochemical parameters

Fasting (overnight for 8 h) venous blood samples were collected for the measurement of serum calcium (N: 8.3–10.4 mg/dL), phosphate (N: 2.5–4.5 mg/dL), alkaline phosphatase (N: 40–125 U/L), albumin (N: 3.5–5.0 g/dL), creatinine (N: 0.6–1.4 mg/dL), 25-hydroxy vitamin D (N: 30–75 ng/mL), and intact parathormone (N: 8–50 pg/mL). Serum calcium, phosphate, albumin, creatinine, and alkaline phosphatase were measured using colorimetric methods using Beckman Coulter (Beckman Coulter AU 5800). An iced sample for intact parathormone (iPTH) was collected and estimated by chemiluminescence assay (Advia Centaur XPT immunoassay system), and 25-hydroxy vitamin D (vitamin D N: 30-75 ng/mL) was measured using electrochemiluminescence assay (Roche Cobas 6000—Immunoassay system). Bone turnover markers, plasma CTX (N: 226-1088 pg/mL in men), and P1NP (N: 16-73.9 ng/mL in men) were measured using electrochemiluminescence immunoassay (ECLIA) on a Roche Elecsys Modular E170 analyzer.

Statistical analyses

Sample size: The sample size estimation was done based on a study by Gao *et al*.[23] that compared the difference in bone mineral density between cases of Parkinson's disease and healthy controls. Assuming an aBMD of 0.670 g/cm^2 at the neck of femur in cases and 0.740 g/cm^2 in controls and a case-control ratio of 1:1, with 80% power at an alpha error of 5% a total of 42 was required in each group.

Assuming a mean difference of 0.07 for an alpha error of 1% and a power of 80%, the sample size was estimated to be 42 in each group.

Continuous variables were expressed as mean and standard deviation, while categorical variables were expressed as frequencies and percentages. Student's t-test was used to compare the means between two groups, while one-way analysis of variance (ANOVA) was used for comparing more than two groups. The post hoc test used to test significance between groups was the Bonferroni correction.

The categorical variables were reported using Chi-square/ Fisher's exact test. Pearson's correlation coefficient was used to assess correlation between various parameters. A two-tailed P value <0.05 was considered statistically significant. Statistical analyses were performed using statistical package for social sciences (SPSS) version 25.0.

Results

A total of 40 subjects with Parkinson's disease (Group-1) and 40 subjects with age, gender, and BMI-matched controls (Group-2) were recruited for this study. The mean (SD) duration of PD was 55.50 (33.20) months, and the median L-dopa dose and modified H&Y score were 375 mg and 2.5, respectively. Other baseline characters are depicted in Table 1. The mean 25 hydroxy vitamin D level was significantly higher in the control group. Vitamin D deficiency (25-hydroxy vitamin D <20 ng/mL) was significantly more in subjects with PD as compared to controls (42.9% vs. 15.2%; $P < 0.01$).

Bone mineral density

The mean (SD) BMD (in grams/cm^2) between the two groups at all skeletal sites is depicted in Table 2. There was no statistically significant difference between the groups for BMD at any site. However, the mean (SD) TBS at the lumbar spine [1.349 (0.090)] was significantly ($P = 0.019$) lower in men with Parkinson's disease as compared to matched controls [1.401 (0.089)]. In the group with PD, age showed significant negative correlation with FN BMD (r = -0.3; $P = 0.04$) and BMI had a significant positive correlation with BMD at the lumbar spine (r = 0.3; $P = 0.04$).

Table 1: Comparison of baseline demographic and biochemical characteristics between the two groups

Variables	Mean (SD)		*P*
	Group-1 (PD) (*n*=40)	Group-2 (Controls) (*n*=40)	
Age (years)	60.5 (6.1)	61.2 (6.2)	0.648
BMI (kg/m^2)	24.2 (3.9)	23.9 (2.1)	0.761
Waist–hip ratio	0.98 (0.05)	0.98 (0.05)	0.86
Albumin corrected calcium (mg/dL)	9.2 (0.5)	9.6 (0.4)	0.112
Serum phosphorus (mg/dL)	3.4 (0.6)	3.5 (0.4)	0.245
Serum alkaline phosphatase (U/L)	80.6 (17.2)	86.3 (19.3)	0.209
Creatinine (mg/dL)	0.89 (0.1)	0.83 (0.1)	0.272
25 hydroxy vitamin D (ng/mL)	22.1 (9.2)	34.1 (11.8)	0.0001
Parathyroid hormone (pg/mL)	61.2 (33.9)	51.7 (20.6)	0.152
CTX* (pg/mL)	455.1 (182.2)	407.9 (169.7)	0.269
P1NP* (ng/mL)	58.1 (24.3)	46.4 (15.2)	0.017
Testosterone (ng/dL)	362.9 (170.8)	393.7 (98.8)	0.346

*CTX = C-terminal telopeptide of type 1 collagen, PINP = Procollagen type 1 N-terminal propeptide

Subjects with Parkinson's disease (Group 1) were subdivided into group 1a (milder disease) with modified H&Y staging ≤2.5, that is, patients without postural instability and group 1b (severe disease) with modified H&Y staging ≥3.0, that is, patients who had postural instability and compared with control group [Table 3]. On subgroup analysis, the vitamin D levels were significantly lower among those with severe disease as compared to those with milder disease and controls. The TBS trended lower in subjects with severe disease. Other subgroup comparisons were not significant.

Among the parameters of hip structural analysis (HSA), the buckling ratios were significantly higher at the femoral neck and inter-trochanteric region among cases as compared to matched controls [Table 4].

Discussion

This is the first Indian study which looked at DXA-derived parameters and bone mineral biochemistry in subjects with Parkinson's disease. While it was found that the BMD at the femoral neck and lumbar spine were not different between cases and matched controls, the trabecular bone score and vitamin D levels were significantly lower among cases as compared to matched controls. Moreover, among the parameters of hip structural analysis, it was found that the buckling ratio at the narrow neck and inter-trochanteric region was higher among cases as compared to controls.

In previous studies, the data have been controversial regarding bone health and Parkinsonism probably due to heterogeneous nature of the studies and confounding factors such as age, sex, disease duration, severity of Parkinsonism, and others. However, our findings were comparable to the studies done by Lam *et al*.[24] and Povoroznyuk *et al*.[25] In a previous study on subjects with Parkinsonism , they were divided into male and female subgroups. The male subgroup on comparing with matched controls showed no difference in the BMD at the lumbar spine and femoral neck, whereas female subgroup with Parkinsonism did show a significant difference in comparison with matched controls.[24] Similarly, in a recent study[25] done in men (N = 38), the mean BMD at the lumbar spine and femoral neck did not differ in relation to the controls, but the total BMD showed a significant difference between the two groups.

"Disuse osteoporosis" refers to the occurrence of bone loss as a result of skeletal unloading or systemic immobilization. Although there are clinical studies that have shown that immobilization leads to loss of cortical as well as trabecular bone, studies involving subjects on prolonged bed rest have demonstrated that bone loss is more severe in the proximal femur as compared to the lumbar spine, that is, the severity of bone loss is greater in weight bearing bones as compared to non-weight bearing bones.[26] In the present study however it is expected that cases with Parkinson's disease are less ambulant as compared to their matched controls, differences in BMD were not apparent. This may be related to the small sample size in this study.

Our study was in sharp contrast to other previous studies done in subjects with Parkinsonism which showed significantly poor bone health.[6,7,24–26] This could be related to our inclusion of a cohort of cases which have a different baseline clinical profile like less severe PD, male gender, lower age, BMI, ethnicity, and various other unknown factors.

Table 2: Comparison of bone mineral density and trabecular bone score between the two groups

Variables	Mean (SD)		*P*
	Group-1 (PD) (*n*=40)	Group-2 (Controls) (*n*=40)	
Femoral neck BMD (g/cm^2)	0.741 (0.097)	0.746 (0.095)	0.822
Total hip BMD (g/cm^2)	0.897 (0.103)	0.922 (0.102)	0.326
Lumbar spine BMD (g/cm^2)	0.974 (0.171)	0.974 (0.143)	0.982
Forearm BMD (g/cm^2)	0.755 (0.061)	0.761 (0.058)	0.692
Trabecular bone score	1.349 (0.090)	1.401 (0.089)	0.019

Table 3: Subgroup analysis of subjects with Parkinson disease compared with age-matched controls

Variables	Mean (SD)			*P* ANOVA	*P* Independent *T*-test		
	Group-1a (*n*=21)	Group-1b (*n*=19)	Group-2 (*n*=40)		Group-1a and 2	Group-1b and 2	Group-1a and 1b
Age (years)	61.8 (6.4)	59.1 (5.4)	61.2 (6.2)	0.329	1.000	0.472	0.712
BMI (kg/m^2)	23.9 (3.8)	24.4 (4.0)	23.9 (2.1)	0.830	1.000	1.000	1.000
Femoral neck BMD (g/cm^2)	0.745 (0.092)	0.737 (0.105)	0.746 (0.095)	0.949	1.000	1.000	1.000
Total hip BMD (g/cm^2)	0.893 (0.106)	0.902 (0.102)	0.922 (0.102)	0.595	0.987	1.000	1.000
Lumbar spine BMD (g/cm^2)	0.989 (0.143)	0.957 (0.201)	0.974 (0.143)	0.822	1.000	1.000	1.000
Forearm BMD (g/cm^2)	0.758 (0.053)	0.752 (0.075)	0.761 (0.058)	0.886	1.000	1.000	1.000
TBS	1.356 (0.081)	1.342 (0.101)	1.401 (0.089)	0.059	0.243	0.088	1.000
25 (OH) vitamin D (ng/mL)	23.9 (9.9)	20.2 (8.1)	34.1 (11.8)	<0.001	<0.001	<0.001	<0.001

Group-1a = Mild Parkinsonism with no postural instability (modified HY stage ≤2.5), Group-1b = Moderate to severe Parkinsonism with postural instability (modified HY stage ≥3.0), Group-2 = Control group

Table 4: Parameters of hip structural analysis compared between cases and controls

HSA Variable	Group-1 (PD) (n=40) Mean (SD)	Group-2 (Controls) (n=40) Mean (SD)	*P*
NN (CSA) cm^2	2.79 (0.68)	3.02 (0.36)	0.083
NN (CSMI) cm^4	2.90 (0.83)	3.75 (1.43)	0.013
NN (Z) cm^3	1.65 (0.33)	1.59 (0.27)	0.765
NN (BR)	11.8 (2.2)	9.4 (2.2)	0.001
IT (CSA) cm^2	5.45 (0.81)	5.41 (0.93)	0.873
IT (CSMI) cm^4	17.06 (4.11)	19.19 (4.59)	0.116
IT (Z) cm^3	4.95 (0.95)	5.07 (1.12)	0.749
IT (BR)	9.4 (2.1)	7.8 (1.4)	0.002
FS (CSA) cm^2	4.66 (0.46)	4.77 (0.53)	0.351
FS (CSMI) cm^4	4.32 (0.74)	4.32 (0.71)	0.994
FS (Z) cm^3	2.64 (0.35)	2.67 (0.33)	0.746
FS (BR)	2.8 (0.7)	2.7 (0.3)	0.175
Hip axis length (HAL) (mm)	113.2 (5.4)	110.9 (3.8)	0.065

CSA = Cross-sectional area, CSMI = Cross-sectional moment inertia, Z = Section modulus, BR = Buckling ratio, NN = Narrow neck, IT = Inter-trochanteric, and FS = Femoral shaft

On subgroup analysis of PD based on disease severity, we found a significantly lower BMD in the subgroup with more severe disease in comparison with the group with less severe disease and controls. These findings were identical to the previous studies done by Jones *et al*.,[27] and Gao *et al*.[23] who found significantly declining BMD with increasing severity of Parkinsonism and relatively more BMD loss in patients with worsening mobility and gait instability.

It was interesting to note that while the bone mineral density was not significantly different between cases and controls, the trabecular bone score was significantly lower among cases. This indicates microarchitectural deterioration, the details of which are not captured by conventional assessment of BMD. It was shown in preclinical studies that osteoporosis is caused by dopaminergic degeneration itself.[27] There is bone loss as well as increased trabecular separation. Moreover, there is increased osteoclastogenesis associated with increased bone resorption associated with dopamine agonist mediated increased prolactin levels. This may explain the microarchitectural deterioration in individuals with PD as compared to healthy controls.

These findings were in contrast to a previously published study, wherein a higher TBS was noted among men with PD as compared to controls.[25] Studies assessing the relationship between vitamin D and TBS are limited. A study from Lebanon, done on 54 males and 61 females aged between 18 and 35 years, showed that there was a significant positive correlation between vitamin D and TBS. Moreover, the TBS was significantly higher in the vitamin D sufficient group as compared to the group with vitamin D deficiency.[28] In the present study, the lower vitamin D may have partially contributed to the lower TBS in cases as compared to controls. However, the contribution of hitherto unknown factors pertaining to the disease contributing to lower TBS needs to be further elucidated.

It was also noted in the present study that parameters of hip structural analysis, such as buckling ratio, were worse among cases as compared to controls. Studies evaluating hip structural analysis in men with PD were not available in literature. This further underscores the possible heightened bone fragility among individuals with Parkinson's disease.

The proportion of individuals with vitamin D deficiency was significantly higher in PD as compared to controls. These findings are in line with the previous findings of Abou Raya *et al*.,[6] Ding *et al*.,[29] and Evatt *et al*.[30] This could probably be related to decreased sunlight exposure and malnutrition in the subjects with PD as they usually confined indoors. Supplementation of vitamin D in deficient people suffering from Parkinsonism may stabilize the disease severity and help in the prevention of falls and probably fractures.[17,31]

Among the bone turnover markers, PINP but not CTX was significantly higher in cases than in controls. Fink *et al*.[7] demonstrated higher bone resorption marker (CTX) to be associated with bone loss in patients with Parkinsonism, and subsequently, Abou Raya *et al*.[6] in a cross-sectional study demonstrated higher P1NP levels in PD.

In subjects with PD, BMD at femoral neck and lumbar spine correlated positively for body mass index (BMI), waist, and hip circumference, whereas it correlated negatively with the duration of disease and its severity as assessed by modified HY staging. There was no correlation with L-Dopa dosage. Previous studies showed mixed results, with Gao *et al*.[23] showing a negative correlation with BMD, severity of disease, and also L-Dopa dosage. Jones *et al*.[32] showed lower BMD with worsening disease stage, and Kao *et al*.[33] showed a similar correlation between PD and BMI as that in our study.

This is the first Indian study that has assessed the bone mineral density and trabecular bone score and bone biochemical parameters and bone turnover markers in male patients with Parkinson's disease and compared them with age, gender, and BMI-matched healthy controls. Moreover, this is the only study that has assessed the hip structural analysis in men with PD as compared to healthy controls. The utility of additional assessment lies in the fact that at times, BMD may not capture all aspects of bone quality. Subjects with PD are elderly and may have degenerative changes of the spine, which may lead to paradoxically high BMD. In such instances, TBS might prove to be a better tool in assessing bone quality and consequent fracture risk. Similarly, a buckling ratio of more than 10 at the narrow neck is indicative of fracture risk. Currently, there are no recommendations to treat based on these additional adjuncts; an individualized decision may need to be made considering other risk factors. This study is limited by its cross-sectional design and relatively small sample size, with a larger proportion of patients with less severe PD being recruited

in the study. Moreover, other factors such as dietary calcium intake and sun exposure were not assessed.

To conclude, the trabecular bone score was significantly lower in subjects with PD as compared to healthy controls, while the bone mineral density was not significantly different. However, in patients with Parkinson's disease associated with more severe disease, BMD was significantly lower at the above skeletal sites in comparison with those with less severe disease and controls. The parameters of hip structural analysis were also significantly impaired among men with PD as compared to healthy controls. Conventional BMD assessment as a stand-alone measure may not suffice in the bone health evaluation of men with PD; additional tools such as the trabecular bone score and hip structural analysis may be required to obtain a comprehensive picture of bone quality and hip geometry in these individuals.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Goetz CG. The history of Parkinson's disease: Early clinical descriptions and neurological therapies. Cold Spring Harb Perspect Med 2011;1:a008862.
2. Hirsch L, Jette N, Frolkis A, Steeves T, Pringsheim T. The incidence of Parkinson's disease: A systematic review and meta-analysis. Neuroepidemiology 2016;46:292–300.
3. Zhang ZX, Román GC. Worldwide occurrence of Parkinson's disease: An updated review. Neuroepidemiology 1993;12:195–208.
4. Singhal B, Lalkaka J, Sankhla C. Epidemiology and treatment of Parkinson's disease in India. Parkinsonism Relat Disord 2003;9(Suppl 2):S105-9.
5. Bharucha NE, Bharucha EP, Bharucha AE, Bhise AV, Schoenberg BS. Prevalence of Parkinson's disease in the Parsi community of Bombay, India. Arch Neurol 1988;45:1321–3.
6. Abou-Raya S, Helmii M, Abou-Raya A. Bone and mineral metabolism in older adults with Parkinson's disease. Age Ageing 2009;38:675–80.
7. Fink HA, Kuskowski MA, Taylor BC, Schousboe JT, Orwoll ES, Ensrud KE, *et al*. Association of Parkinson's disease with accelerated bone loss, fractures and mortality in older men: The Osteoporotic Fractures in Men (MrOS) study. Osteoporos Int 2008;19:1277–82.
8. Invernizzi M, Carda S, Viscontini GS, Cisari C. Osteoporosis in Parkinson's disease. Parkinsonism Relat Disord 2009;15:339–46.
9. van den Bos F, Speelman AD, Samson M, Munneke M, Bloem BR, Verhaar HJJ. Parkinson's disease and osteoporosis. Age Ageing 2013;42:156–62.
10. Kalilani L, Asgharnejad M, Palokangas T, Durgin T. Comparing the incidence of falls/fractures in Parkinson's disease patients in the US population. PLoS One 2016;11:e0161689.
11. Tassorelli C, Berlangieri M, Buscone S, Bolla M, De Icco R, Baricich A, *et al*. Falls, fractures and bone density in Parkinson's disease - A cross-sectional study. Int J Neurosci 2017;127:299–304.
12. Bloem BR, Hausdorff JM, Visser JE, Giladi N. Falls and freezing of gait in Parkinson's disease: A review of two interconnected, episodic phenomena. Mov Disord 2004;19:871–84.
13. Pouwels S, Bazelier MT, de Boer A, Weber WEJ, Neef C, Cooper C, *et al*. Risk of fracture in patients with Parkinson's disease. Osteoporos Int 2013;24:2283–90.
14. Sleeman I, Che ZC, Counsell C. Risk of fracture amongst patients with Parkinson's disease and other forms of parkinsonism. Parkinsonism Relat Disord 2016;29:60–5.
15. Park SB, Chung CK, Lee JY, Lee JY, Kim J. Risk factors for vertebral, hip, and femoral fractures among patients with Parkinson's disease: A 5-year follow-up in Korea. J Am Med Dir Assoc 2019;20:617–23.
16. Hosseinzadeh A, Khalili M, Sedighi B, Iranpour S, Haghdoost AA. Parkinson's disease and risk of hip fracture: Systematic review and meta-analysis. Acta Neurol Belg 2018;118:201–10.
17. Torsney KM, Noyce AJ, Doherty KM, Bestwick JP, Dobson R, Lees AJ. Bone health in Parkinson's disease: A systematic review and meta-analysis. J Neurol Neurosurg Psychiatry 2014;85:1159–66.
18. Dhanwal DK, Siwach R, Dixit V, Mithal A, Jameson K, Cooper C. Incidence of hip fracture in Rohtak district, North India. Arch Osteoporos 2013;8:135.
19. Paul TV, Selvan SA, Asha HS, Thomas N, Venkatesh K, Oommen AT, *et al*. Hypovitaminosis D and other risk factors of femoral neck fracture in South Indian postmenopausal women: A pilot study. J Clin Diagn Res JCDR 2015;9:OC19-22.
20. Writing Group for the ISCD Position Development Conference. Position statement : Executive summary. The Writing Group for the International Society for Clinical Densitometry (ISCD) Position Development Conference. J Clin Densitom 2004;7:7–12.
21. Rajan R, Cherian KE, Kapoor N, Paul TV. Trabecular bone score-an emerging tool in the management of osteoporosis. Indian J Endocrinol Metab 2020;24:237–43.
22. Cherian KE, Kapoor N, Meeta M, Paul TV. Dual-energy X-ray absorptiometry scanning in practice, technical aspects, and precision testing. J Life Health 2021;12:252–6.
23. Gao H, Wei X, Liao J, Wang R, Xu J, Liu X, *et al*. Lower bone mineral density in patients with Parkinson's disease: A cross-sectional study from Chinese Mainland. Front Aging Neurosci 2015;7:203.
24. Lam K, Li M, Mok V, Hui A, Woo J. A case control study on bone mineral density in Chinese patients with Parkinson's disease. Parkinsonism Relat Disord 2010;16:471–4.
25. Povoroznyuk V, Bystrytska M, Grygorieva N, Karaban I, Karasevich N. Bone mineral density, TBS, and body composition indexes in Ukrainian men with Parkinson's disease. Park Dis 2019;2019:9394514.
26. Beller G, Belavý DL, Sun L, Armbrecht G, Alexandre C, Felsenberg D. WISE-2005: Bed-rest induced changes in bone mineral density in women during 60 days simulated microgravity. Bone 2011;49:858–66.
27. Handa K, Kiyohara S, Yamakawa T, Ishikawa K, Hosonuma M, Sakai N, *et al*. Bone loss caused by dopaminergic degeneration and levodopa treatment in Parkinson's disease model mice. Sci Rep 2019;9:13768.
28. Alwan A, Al Rassy N, Berro AJ, Rizkallah M, Matta J, Frenn F, *et al*. Vitamin D and trabecular bone score in a group of young lebanese adults. J Clin 2018;21:453–8.
29. Ding H, Dhima K, Lockhart KC, Locascio JJ, Hoesing AN, Duong K, *et al*. Unrecognized vitamin D3 deficiency is common in Parkinson disease: Harvard Biomarker Study. Neurology 2013;81:1531–7.
30. Evatt ML, Delong MR, Khazai N, Rosen A, Triche S, Tangpricha V. Prevalence of vitamin d insufficiency in patients with Parkinson disease and Alzheimer disease. Arch Neurol 2008;65:1348–52.
31. Suzuki M, Yoshioka M, Hashimoto M, Murakami M, Noya M, Takahashi D, *et al*. Randomized, double-blind, placebo-controlled trial of vitamin D supplementation in Parkinson disease. Am J Clin Nutr 2013;97:1004–13.
32. Jones PD, Stone D, Jones S, Lewis B. Parkinson's disease and bone health. Age Ageing 2010;39:278.
33. Kao CH, Chen CC, Wang SJ, Chia LG, Yeh SH. Bone mineral density in patients with Parkinson's disease measured by dual photon absorptiometry. Nucl Med Commun 1994;15:173–7.