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Correlation between bone mineral density of different sites and lumbar disc degeneration in postmenopausal women

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Abstract

Osteoporosis and lumbar disc degeneration (LDD) have been common causes that make increasing patients suffer from different degrees of low back pain. At present, whether osteoporosis degenerates or protects disc is still controversial, and the correlation between hip bone mineral density (BMD) and LDD still remains unclear. Our study aims to analyze the correlation between BMD of different sites and LDD in postmenopausal women, and explore the potential pathophysiological mechanism of them.

One hundred ninety-five postmenopausal female patients were enrolled and divided into osteoporosis, osteopenia, and normal bone mass groups. Their BMD and lumbar spine magnetic resonance imaging were retrospectively analyzed. Two spine surgeons were selected to assess LDD according to Pfirrmann grading system.

Based on lumbar BMD, LDD of normal bone mass group was more severe than the other 2 groups in L1/2 and L2/3 segments ($P < .05$). Based on hip BMD, LDD of each disc from L1/2 to L5/S1 had no significant difference among the 3 groups ($P > .05$). Lumbar BMD (L1-L4) was positively correlated with corresponding degree of LDD (L1/2-L4/5) ($P < .05$), whereas there was no correlation between hip BMD and degree of LDD ($P = .328$).

There is a positive correlation between lumbar BMD and LDD in postmenopausal women, which is more obvious in the upper lumbar spinal segments (L1, L2). However, there is no correlation between hip BMD and LDD, suggesting that in postmenopausal women with lumbar degenerative disease, hip BMD is more suitable for the diagnosis of osteoporosis.

Abbreviations: BMD = bone mineral density, BMI = body mass index, ICC = interclass correlation coefficient, LDD = lumbar disc degeneration, MRI = magnetic resonance imaging.

Keywords: bone mineral density, correlation study, lumbar disc degeneration, osteoporosis

1. Introduction

With the aging of the population, spinal diseases are increasingly common in musculoskeletal diseases. 50% to 80% of adults have experienced low back pain at least once in their lifetime.[1] Osteoporosis and lumbar disc degeneration (LDD) are both important causes of low back pain which seriously affects the quality of life of patients.[2,3] The estrogen level in postmenopausal women decreases rapidly, meanwhile, with the increase of menopause years, the bone mineral density (BMD) of women changes greatly, and the LDD is more serious than that of men of the same age.[4]

In the past decades, some scholars support a negative correlation between lumbar spine BMD and LDD, that is, lower BMD signifies severer LDD. They suggest that osteoporosis may be the cause of LDD. Low lumbar spine BMD leads to loss of vertebral height and spinal instability, which will result in facet joint and disc degeneration.[5,6] A few studies have shown that there is no definite correlation between the 2.[7] Other studies have given the opposite conclusion that osteoporosis is conducive to the nutrient diffusion in discs, and reduces the stress of discs due to the decrease of BMD, which indicate a positive correlation between BMD and LDD.[8,9]

After years of research, whether osteoporosis degenerates or protects disc is still controversial. At present, few scholars have studied the correlation between hip BMD and LDD, which still remains unclear. The purpose of this study is to analyze the correlation between BMD of different sites and LDD in

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The case was reviewed by ShuGuang Hospital Ethics Committee. We obtained ethical approval exemption from our ethics committee to perform this study since we did not have direct contact with the participants.

Written patient consent was obtained for publication of all aspects of the case including personal and clinical details and images, which may compromise anonymity.

All supporting data can be provided upon request to the authors.

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The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

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postmenopausal women, and to explore the potential pathophysiological mechanism of them.

2. Materials and methods

2.1. Patient case selection

Database records of postmenopausal female patients treated for back, buttock, and/or lower extremity pain in our hospitals were retrospectively reviewed from January 1, 2018, to January 1, 2020 (our hospitals began to use a new medical record system on January 1, 2018). Ethical approval exemption was obtained from our ethics committee as we had no direct contact with patients.

Patients involved in the study should have performed both BMD (including lumbar spine and hip) and lumbar spine magnetic resonance imaging (MRI) within 2 weeks. Complete clinical data (including demographic characteristics, chief complaint, medical history and relevant treatment) were required. Exclusion criteria were as follows: trauma, infection, tumor, congenital deformity, and previous surgery of lumbar spine; metabolic bone disease, chronic hepatitis, and chronic kidney disease affecting bone metabolism; secondary osteoporosis caused by hyperparathyroidism and long-term using of glucocorticoid; rheumatoid, ankylosing spondylitis, and other immune system diseases; and patients who had used vitamin D, calcium, bisphosphate, and other drugs affecting bone metabolism within 6 months. One resident of our department who did not participate in the later statistics and analysis collected the cases from our database of patients. Finally, 195 consecutive cases meeting the criteria were included. The age, height, weight, diabetes, hypertension, drinking, and smoking history of the patients were recorded.

2.2. Measurement and assessment

2.2.1. BMD. Performed by professionals, using dual-energy X-ray absorptiometry to check the BMD of lumbar spine (L1-L4) and hip. Corresponding T values of the patient's lumbar (L1-L4) vertebra and hip were recorded. Diagnose according to the WHO's classification (based on T value of BMD) of osteoporosis, with T value ≥ -1.0 considered normal, $-2.5 <$ T value < -1.0 considered osteopenia, T value ≤ -2.5 considered osteoporosis. In addition, based on the BMD of different sites, we divided the cases into the total body BMD group: as long as 1 of the 4 parts (L1-L4 vertebrae, femoral neck, greater trochanter, and total hip) had a T value of < -2.5, it could be diagnosed as osteoporosis; the lumbar spine BMD group: based on the average BMD of L1-L4 vertebrae; and the hip BMD group: based on the average BMD of total hip.

2.2.2. Degree of LDD. The MRI data of lumbar spine were scanned by 1.5T whole-body imaging system (Siemens Medical, Germany) and stored in database of Picture Archiving and Communication System (PACS). T2 weighted images of intervertebral discs from L1/L2 to L5/S1 were collected for identification and evaluation. According to the Pfirrmann grading system,[10] degree of LDD was divided into grades I-V based on disc signal intensity, disc structure, distinction between nucleus and anulus, and disc height. The 5 grades represented the scores of 1-5 points, respectively. The higher score signified the more severe degree of LDD. The classification and score were assessed by 2 senior spine surgeons through discussion and evaluation sessions. For each case, the mean level of LDD was defined as the average of 5 grading scores derived from L1/L2 to L5/S1.

2.3. Statistical analysis

We used Statistical Packages of Social Sciences (SPSS) software (version 25.0) to conduct the statistics and analyze the data. Counting data such as diabetes, hypertension were expressed as percentage, and chi-square test was used to compare the differences among groups. Measurement data such as weight, height were expressed as mean ± standard deviation ($\overline{x} \pm s$), and analysis of variance (ANOVA) was used to compare the differences among groups. The degree of LDD of different groups based on BMD were compared through analysis of covariance, while age and body mass index (BMI) were included in the analysis of covariance to exclude such confounding factors. For comparison of differences among groups, Least-Significant-Difference (LSD) was performed. Spearman correlation coefficient was used to analyze the correlation between lumbar/hip BMD and the severity of LDD. P values of $<.05$ were considered statistically significant for all the above. The inter-observer reliability of LDD grades was expressed by interclass correlation coefficient (ICC),[11] with ICC valuing 0.00 to 0.40 considered poor agreement, 0.40 to 0.74 fair to good agreement, and 0.75 to 1.00 excellent agreement.[12,13]

3. Result

A total of 195 consecutive cases were involved in the current study, with an average age of 63.1 ± 10.8 years (range from 42 to 88 years) and an average BMI of 25.27 ± 3.18 kg/m^2 (range from 17.94 to 35.61 kg/m^2). Seventy-nine patients had hypertension. Thirty-six patients had diabetes. Twenty-one patients drank and 15 patients smoked. According to Pffirmann classification system, there were 94 discs of grade I, 201 discs of grade II, 332 discs of grade III, 270 discs of grade IV, and 78 discs of grade V. Based on the total BMD, the age of osteoporosis and osteopenia group was significantly higher than that of normal bone mass group, the BMI of osteoporosis group was lower than that of normal bone mass group, the grade II LDD of osteoporosis group was significantly more than that of normal bone mass group, and the grade III LDD of osteoporosis group was significantly less than that of normal bone mass group ($P < .05$). There was no significant difference among the 3 groups in other general data ($P > .05$, Table 1).

3.1. Inter-observer reliability of LDD grades

The inter-observer agreement of LDD grades between the 2 spine surgeons were entirely excellent. The ICC values of each lumbar disc from L1/L2 to L5/S1 and the total were as follows: 0.823, 0.861, 0.875, 0.776, 0.831, and 0.847, respectively. The overall ICC value was 0.855. All of the results were considered statistically significant ($P < .05$) (Table 2).

3.2. LDD scores in different groups

The LDD scores (grade I-V represented the score of 1-5 points) in the groups based on average hip and lumbar BMD were shown in Table 3.

Based on lumbar BMD, normal bone mass group had higher mean LDD score from L1/2 to L5/S1 discs than the other 2

Table 1

Comparison of general information among groups based on total BMD.

No.	Content	Group			*P* value		
		A (normal) N = 65	B (osteopenia) N = 59	C (osteoporosis) N = 71	A-B	A-C	B-C
1	Age	56.29 ± 13.91	63.82 ± 11.57	66.24 ± 14.73	.015*	.007*	.322
2	BMI	25.02 ± 3.08	24.63 ± 3.52	23.57 ± 2.96	.140	.026*	.081
3							
	LDD (Pfirrmann)						
	Grade I	27 (8.3%)	22 (7.5%)	45 (12.7%)	.428	.291	.216
	Grade II	41 (12.6%)	59 (20%)	101 (28.5%)	.225	.026*	.197
	Grade III	130 (40%)	103 (34.9%)	99 (27.9%)	.327	.019*	.118
	Grade IV	98 (30.2%)	89 (30.2%)	83 (23.4%)	.542	.273	.205
	Grade V	29 (8.9%)	22 (7.5%)	27 (7.6%)	.471	.608	.855
4	Hypertension	24 (36.9%)	26 (44.1%)	34 (47.9%)	.075	.069	.194
5	Diabetes	14 (21.5%)	11 (18.7%)	17 (23.9%)	.218	.155	.137
6	Drinking	8 (12.3%)	6 (10.2%)	10 (14.1%)	.254	.436	.092
7	Smoking	6 (9.2%)	4 (6.8%)	7 (9.9%)	.379	.628	.577

BMD = bone mineral density, BMI = body mass index, LDD = lumbar disc degeneration.
* The difference between the 2 groups was significant.

groups, and the differences were significant in L1/2 and L2/3 segments ($P < .05$). In addition, the LDD scores of normal bone mass group and osteopenia group were significantly higher than that of osteoporosis group in L4/5 segment ($P < .05$). Except for this, there was no significant difference between osteopenia group and osteoporosis group.

Based on hip BMD, the LDD scores of each disc from L1/2 to L5/S1 segments had no significant difference among the 3 groups ($P > .05$) (Table 3).

Table 2

Inter-observer reliability of LDD grades between spine surgeons.

Disc level	Inter-observer reliability	
	ICC	*P*
L1/2	0.823	<.001*
L2/3	0.861	.005*
L3/4	0.875	<.001*
L4/5	0.776	.008*
L5/S1	0.831	.002*
Total (L1-S1)	0.847	<.001*

ICC = interclass correlation coefficient, LDD = lumbar disc degeneration.
* The inter-observer reliability of LDD grades between the 2 spine surgeons was significant.

3.3. Correlation between BMD and LDD

The correlation between BMD of different sites and LDD was shown in Table 4.

The BMD of each lumbar vertebra (L1-L4) was positively correlated with the total mean LDD scores (L1/2-L5/S1) ($P < .05$), whereas there was no correlation between the BMD of hip and the degree of LDD ($P = .328$). MRI showed that under similar conditions (age and BMI), patients with higher lumbar BMD (Fig. 1A) had more severe stenosis of intervertebral space and higher Pfirrmann scores than those with lower lumbar BMD (Fig. 1B), which possibly meant that the higher bone mass signified the more serious LDD.

4. Discussion

Osteoporosis and lumbar degenerative diseases have become the most common chronic diseases in orthopedics. The cost of treatment has caused a huge economic burden on society. As we all know, BMD in postmenopausal women is declining much faster than that in men of the same age. In addition, through a large sample study, Lou et al[14] indicated that the degree of LDD in postmenopausal women was significantly higher. Therefore, the change of BMD may be closely related to the severity of LDD. In our study, postmenopausal women were divided into osteoporosis, osteopenia, and normal bone mass group

Table 3

LDD scores based on average lumbar and hip BMD.

Disc level	LDD scores based on average lumbar BMD				LDD scores based on average hip BMD			
	A (normal) N = 75	B (osteopenia) N = 62	C (osteoporosis) N = 58	*P*	A (normal) N = 71	B (osteopenia) N = 63	C (osteoporosis) N = 61	*P*
L1/2	2.58 ± 0.88	2.26 ± 0.97*	2.18 ± 0.95*	.021	2.49 ± 0.92	2.35 ± 1.10	2.32 ± 0.95	.158
L2/3	3.06 ± 0.91	2.68 ± 0.75*	2.60 ± 0.84*	.029	2.91 ± 0.95	2.75 ± 0.87	2.73 ± 0.84	.427
L3/4	3.24 ± 0.74	3.18 ± 0.82	3.10 ± 1.02	.547	3.27 ± 0.75	3.14 ± 0.91	3.19 ± 1.02	.592
L4/5	3.57 ± 0.95	3.52 ± 0.59†	3.21 ± 0.81*	.035	3.43 ± 0.83	3.58 ± 0.69	3.45 ± 0.81	.417
L5/S1	3.64 ± 0.68	3.39 ± 0.93	3.47 ± 0.72	.469	3.55 ± 0.77	3.42 ± 0.82	3.44 ± 0.72	.633
L1-S1	3.22 ± 0.52	3.01 ± 0.49*	2.91 ± 0.47*	.018	3.13 ± 0.52	3.05 ± 0.49	3.03 ± 0.47	.105

BMD = bone mineral density, LDD = lumbar disc degeneration.
* Compared with Group A (normal bone mass), the difference was significant ($P < .05$).
† Compared with Group C (osteoporosis), the difference was significant ($P < .05$).

Table 4

Correlation between BMD of different sites and LDD.

BMD scores	Mean LDD scores (L1-S1)	
	r	*P*
L1	0.213	.002*
L2	0.169	.026*
L3	0.205	.004*
L4	0.157	.031*
L1-4	0.201	.004*
Hip	0.059	.328

BMD = bone mineral density, LDD = lumbar disc degeneration.
* The correlation between BMD and LDD was significant ($P < .05$).

according to BMD (T value) of different parts. The correlation between lumbar and hip BMD and lumbar disc degeneration was discussed respectively. Our results suggested that lumbar BMD was positively correlated with degree of LDD, especially in upper lumbar segments (L1, L2), whereas hip BMD had no correlation with LDD.

Some previous studies showed that compared with normal people, patients with osteoporosis had not only higher intervertebral space in, but also lower severity of LDD. Based on these results, some scholars pointed out that lumbar BMD is positively correlated with LDD, which meant that higher vertebral BMD was often accompanied by more severe LDD.[15–17] Therefore, our results were consistent with those studies. In addition, to avoid the false elevation of vertebral BMD caused by lumbar proliferative degeneration, Wang et al[17] conducted an autopsy of 48 white cadavers and found at first that there was no correlation between corresponding vertebral BMD and adjacent LDD. However, after resection of spinous process, and removing osteophyte and cartilage endplate through micro computed tomography techniques, higher vertebral BMD was found to have significant positive correlation with more serious adjacent LDD, which indicated that the increase of vertebral BMD leading to more severe LDD was not only caused by osteophyte formation and calcification of endplate.

The pathophysiological mechanisms of increased BMD leading to more severe LDD are as follows: With the degenerative changes of lumbar disc, the water content of nucleus pulposus decreases, which will lead to nucleus pulposus fibrosis, endplate calcification and formation of peripheral osteophyte. This may increase the BDM of vertebral peripheral wall while mildly reduce the BDM of central trabecular bone, and thus will explain why the lumbar BMD increases.[18] The vertebra with higher BMD has a more dense bone microstructure, which makes it difficult for the vascular buds nourishing endplates to grow. The decrease in the number and size of the vascular buds will hinder the blood supply of the intervertebral

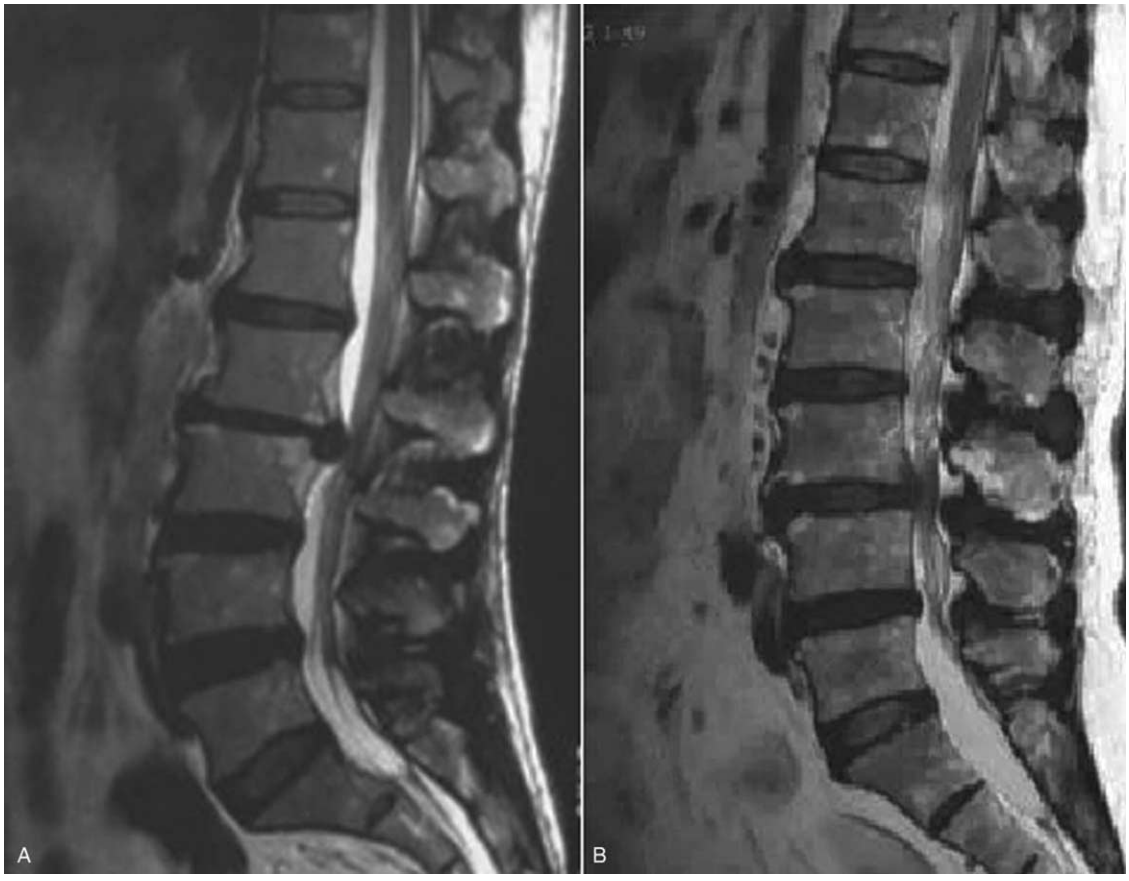

Figure 1. MRI evaluation of LDD in patients under similar conditions with different lumbar BMD. (A) 77-year-old female, BMI 23.26 kg/m^2, total lumbar BMD: T value –0.2 (normal bone mass), mean scores of LDD: 3.8 (L1-S1). (B) 74-year-old female, BMI 22.84 kg/m^2, total lumbar BMD: T value –2.9 (osteoporosis), mean scores of LDD: 3.2 (L1-S1). BMD = bone mineral density, BMI = body mass index, LDD = lumbar disc degeneration, MRI = magnetic resonance imaging.

disc and promote the occurrence of LDD.[19,20] The high vertebral BMD increases the pressure in endplate and intervertebral disc. The increase in the static compression force of the endplate reduces the level of glucose diffusion to the disc. Meanwhile, the affected endplate will transfer the pressure to the disc, thereby reducing its own stress. That is, the high vertebral BMD increasing the inner stress of adjacent lumbar disc, thus reducing the diffusion of nutrients such as glucose, finally promotes the adjacent LDD.[21,22]

Our results showed that the positive correlation between lumbar BMD and LDD was more significant in the upper lumbar spinal segments than in the lower ones, which was contrary to previous studies.[23,24] The specific reasons for the lumbar regional differences were not clear, but the age might be one of the reason. Through observation, we found that the average age of our cases was higher than previous studies, and thus the LDD of the upper lumbar segment was correspondingly more serious, which might make the positive correlation between BMD and LDD of the upper lumbar segment more significant. Generally, the BMD of upper lumbar segments was lower than that of lower lumbar segments, and the LDD of upper lumbar segments was milder as well.[25,26] Some scholars indicated that the positive correlation was more significant in the lower lumbar segments, for there was more physical weight-bearing.[27] However, the lower lumbar segments were more prone to endplate sclerosis and abnormal osteophyte formation, which would lead to the increase of BMD and affect the correlation between lumbar BMD and LDD. Therefore, it was believed that the correlation between BMD of upper lumbar spinal segments and LDD was more accurate.

Few scholars have studied the correlation between hip BMD and LDD. Our study found that hip BMD was not related to LDD. Wang et al[28] analyzed 196 females and 163 males over 67 years old, and pointed out that LDD scores were related to lumbar BMD, but not to femoral neck BMD. This difference indicated that degenerative spinal diseases (cartilage endplate calcification, osteophyte hyperplasia, etc) could increase the measurements of lumbar BMD. These results suggested that hip BMD was more suitable for the diagnosis of osteoporosis in patients with lumbar degenerative disease.

The current study had several limitations. First of all, the degree of LDD lacked quantitative analysis. Pfirrmann grading system was a relatively subjective measurement standard which might have human errors and cause deviation of results. Secondly, lack of animal research. Our finding that the positive correlation between lumbar BMD and LDD was more significant in the upper lumbar spinal segments was contrary to the previous study, however, the specific reasons or mechanisms were not clear. Therefore, further animal research might help us obtain a definite subversive result. Thirdly, as proliferative osteophyte or endplate sclerosis was a confounding variable to be controlled which may interfere with the accuracy of BMD measurement, we did not perform full-length spinal radiographs which could help to evaluate the osteophytes and sclerosis. Thus, animal-based, high-quality, large sample and multicenter studies should be performed in our future work to provide spine surgeons with the best evidence-based information.

5. Conclusion

There is a positive correlation between lumbar BMD and LDD in postmenopausal women, which is more obvious in the upper lumbar spinal segments (L1, L2). However, there is no correlation between hip BMD and LDD, suggesting that in postmenopausal women with lumbar degenerative disease, hip BMD is more suitable for the diagnosis of osteoporosis. In addition, for outpatients performing BMD screening, higher lumbar BMD often means more severe LDD, thus we recommend further computed tomography or MRI examination. Exploring the correlation between BMD and LDD is of great significance for understanding the occurrence and development of senile degenerative spinal diseases, and is helpful for clinical decision-making in the diagnosis and treatment of osteoporosis and LDD.

Author contributions

Lin Zhou designed the study and collected the data. Cheng Li did the data analysis. Lin Zhou and Cheng Li wrote the manuscript together. Hao Zhang revised the manuscript and decided to submit the manuscript for publication. All authors read and approved the final manuscript.

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