Effect of the lumbar scoliosis on the results of dual-energy X-ray absorptiometry

Nikola Kirilov,[1] Elena Kirilova,[2] Svilen Todorov,[1] Nikolay Nikolov[2]

[1]Department of Orthopedics and Traumatology, and [2]Department of Rheumatology, University Hospital "Dr. Georgi Stranski", Pleven, Bulgaria

Abstract

One of the most common causes of lumbar scoliosis in adults is the decreased bone mineral density (BMD). The scoliosis in the lumbar spine has a known effect over the dual-energy X-ray absorptiometry (DXA) scan results. The objective of this study is to assess the influence of the lumbar scoliosis on the results of the DXA scan of the lumbar spine. 1019 women aged ≥40 years underwent a DXA scan of the spine. Age, weight, height, total BMD, total T-score of the lumbar spine were recorded. The angle of the lumbar scoliosis (Cobb's angle) was measured from the DXA scan image using a DICOM software. The incidence of lumbar scoliosis in the current study accounts to 12.3%. Women with scoliosis showed significantly higher incidence of discrepancy in BMD T-scores between the adjacent vertebrae by more than 1 SD compared to women without scoliosis, (p=0.046). DXA results of subjects with scoliosis require more detailed evaluation of the T-scores of each vertebra to make a prompt decision about the final diagnosis.

Introduction

Scoliosis is defined as a lateral deviation from the normal vertical line of the spine. Lumbar scoliosis is one of the most common problems caused by spinal degeneration in older people.[1] Its incidence ranges from 7.5% to 13.3%.[2] In previous studies, by measuring the Cobb's angle from DXA scans, lumbar spine scoliosis was defined as Cobb's angle ≥ 10°.[3-6] In Bulgaria, scoliosis is graded according to Chaklin's classification and four grades are defined according to the angle of the spinal curvature: grade 1 – degree of 5-10°, grade 2 – degree of 10-25°, grade 3 – degree of 25-45° and grade 4 – degree of 45-75°. Several published studies have shown that DXA image could be used to detect lumbar scoliosis.[7] Pappou *et al*. found that Cobb's angle measured from DXA image strongly correlates with the Cobb's angle assessed from lumbar radiography.[7] In a large retrospective study lumbar scoliosis has also been detected using Cobb's angle measurement from a DXA image and its prevalence was examined in 7.075 individuals aged ≥ 40 years.[8] Therefore, DXA as a gold-standard method for assessment of the BMD could also serve to conduct large studies for identification of the prevalence of lumbar scoliosis.[9] DXA is recommended for women aged ≥65 years regardless of the risk factors, all postmenopausal women under 65 years with at least one risk factor and women around the menopause with several significant risk factors.[10] On the one hand, it has been suggested that low BMD could be a potential risk factor for the formation of degenerative lumbar scoliosis[11,12] and lumbar scoliosis could also reflect on the interpretation of DXA results.[13-16] However, lumbar scoliosis and osteoporosis are common problems in the elderly population and usually occur simultaneously.[17] According to the recommendations of the International Society for Clinical Densitometry (ISCD), the BMD values of all four vertebrae (L1-L4) should be included to calculate the average BMD and total T-score. In addition, it is suggested that BMD T-score discrepancy >1.0 standard deviation (SD) between the adjacent vertebrae may indicate a vertebral fracture, and it is recommended to exclude such vertebrae from the analysis.[13,14] The purpose of this study is to evaluate the effect of lumbar scoliosis on the DXA scan results.

Correspondence: Nikola Kirilov, Department of Orthopedics and Traumatology, University Hospital "Dr. Georgi Stranski, Sveta Bogoroditsa 68, 6000, Stara Zagora, Bulgaria
Tel. +359882107052
E-mail: kirilov_9@abv.bg

Key words: lumbar scoliosis, DXA, effect, results.

Contributions: The authors contributed equally.

Conflict of interest: The authors declare no potential conflict of interests.

Funding: None

Availability of data and materials: The authors confirm that the data supporting the findings of this study are available within the article.

Ethical approval: All procedures performed were in accordance with the ethical standards of the institutional and/or national research committee.

Informed consent: Informed consent was obtained from all individual participants included in the study.

Received for publication: 25 January 2020.
Accepted for publication: 16 April 2020.

Orthopedic Reviews 2020;12:8477
doi:10.4081/or.2020.8477

Materials and Methods

In this study, 1019 women aged ≥40 years underwent DXA scans in the University hospital of Pleven "Dr. Georgi Stranski". We evaluated lumbar scoliosis from DXA images by measuring Cobb's angle using DICOM software. Chaklin's classification of scoliosis was used to identify and classify lumbar scoliosis. Three groups of women have been formed according to this classification. The first group was defined as Cobb's angle <5° and identified the absence of lumbar scoliosis. The second group consisted of women with Cobb's angle between 5° and 10° and the third group included women with Cobb's angle above 10°. Information about age, height, weight, total BMD values of L1-L4 in g/cm^2 and total T-score in standard deviations (SDs) of L1-L4 was collected from DXA scans. According to the maximum difference in the T-scores of the adjacent vertebrae, we formed two groups –first group with a maximum difference in T-scores ≤ 1 SDs and second group with a maximum difference in T-scores > 1 SDs. Statistical analysis was performed using SPSS version 19. Descriptive statistic was used to calculate mean values, standard deviations, standard errors, minimum and maximum values. Chi-square test was used to investigate the relationship between two qualitative variables. Statistically significant difference was defined as p-value <0.05.

Results

After performing a descriptive statistical analysis, we found that 1019 women were with mean age 60.84 years (yrs) ± 9.5 yrs and range (40-89 yrs). The average height of the women was 160.22±9.3 cm (range 140 cm to 185 cm) and the average weight was 70.56±15.3 kg. SD (range 48-165 kg). The average total BMD of L_1-L_4

was 0.865±0.194 g/cm² with range (0.44 g/cm²-2.70 g/cm²), and the average total T-score of L_1-L_4 was -1.65±1.752 SDs (range -5.6 SDs to 14.80 SDs). The mean value of the maximum difference in T-scores of L_1-L_4 was 1.38±0.894 SDs with a range from 0 SDs to 7.3 SDs. Cobb's angle was measured for all 1019 subjects and was on average 2.76±2.53° SDs (Table 1).

894 of all 1019 women (87.7%) were in the first group according to their Cobb's angles (with Cobb's angle <5°). 106 women (10.4%) were attributed to the second group (Cobb's angle 5°-10°) and 19 women (1.9%) were attributed to the third group (Cobb's angle >10°). The incidence of lumbar spine scoliosis in the current study accounts to 12.3% (125/1019 women).

The women in the first group (with Cobb's angle <5°) were with mean age 60±9 yrs (range 40-87 yrs). The mean height of those women was 160±10 cm (minimum 140 cm and maximum 185 cm) and the mean weight was 71±15.3 kg. (minimum 48 kg and maximum 165 kg). The total BMD of L_1-L_4 and the total T-score of L_1-L_4 have been measured for 894 of the women and were on average 0.86±0.19 g/cm² (minimum 0.44 g/cm² and maximum 2.70 g/cm²) and -1.68±1.74 SDs (minimum -5.6 SDs and maximum 14.80 SDs), respectively. The mean of the maximum difference between T–scores of L_1-L_4 in the first group was -1.34±0.87 SDs (minimum 0 SDs and maximum 7.3SDs). Cobb's angle was on average 2.1±1.3° SDs (Table 2).

The women in the second group (with Cobb's angle 5-10° were with mean age of 65±10 yrs and range 41-87 yrs). The mean height was 161±6 cm (minimum 146 cm and maximum 174 cm) and the average weight was 70±15 kg (minimum 42 kg and maximum 110 kg). Total BMD of L_1-L_4 and total T-score of L_1-L_4 were available for all 106 subjects in the second group and were on average 0.90±0.21g/cm² (minimum 0.54 g/cm² and maximum 1.61 g/cm²) and -1.31±1.88 SDs (minimum -4.6 SDs and maximum 5.10 SDs), respectively. The mean of the maximum difference between T-scores of L_1-L_4 in this group was 1.623±0.93 SDs (minimum 0.3 and maximum 5.4 SDs). Cobb's angle was on average 6.5±1.4° SDs (Table 3).

The women in the third group (with Cobb's angle >10°) were with mean age 66±10 yrs (range 43-89 yrs). The average height was 159±7 cm (minimum 159 cm and maximum170 cm). Mean weight was 63±15 kg (minimum 41 kg and maximum 105 kg). The average total BMD of L_1-L_4 was 0.78±0.12 g/cm² (minimum 0.60g/cm² and maximum 1.10g/cm²) and the average total T-score of L_1-L_4 was -2.45±1.11 SDs (minimum -4.1 SDs and maximum 0.50 SDs), respectively. The mean of the maximum difference between T–scores of L_1-L_4 in the third group was 0.869 SDs ± 0.675 SDs (minimum 0.1 SDs and maximum 2.2SDs). Cobb's angle was on average 14.3±5.3° SDs (Table 4).

According to the maximum difference in the T-scores of the adjacent vertebrae, 591 of 1019 women (57.9%) were attributed to the first group with a maximum difference in T-scores ≤1 SD. 428 of 1019

Table 1. Data collected from DXA scans.

	Count (N)	Min	Max	Mean	SDs
Age (years)	1019	40	89	60.84	9.501
Height (cm)	1019	140	185	160.22	9.265
Weight(kg)	1019	48	165	70.56	15.265
Total BMDL1-L4 (g/cm²)	1019	.44	2.70	.8645	.19437
Total T-score L1-L4 (SD)	1019	-5.60	14.80	-1.6532	1.75174
Max difference between T-score L1-L4 (SD)	1019	.0000	7.3000	1.376840	.8938413
Cobb's angle (°)	1019	.0000	30.0388	2.762553	2.5269054

Table 2. Characteristics of the women with Cobb's angle <5°

	Characteristics					
	Mean	Max	Min	Count (N)	SD	Standard Error
Age (years)	60	87	40	894	9	0
Height (cm)	160	185	140	894	10	0
Weight(kg)	71	165	48	894	15	1
Total BMDL1-L4 (g/cm²)	.86	2.70	.44	894	.19	.01
Total T-score L1-L4 (SD)	-1.68	14.80	-5.60	894	1.74	.06
Max difference between T-score L1-L4 (SD)	1.3412	7.3000	.0000	894	.8701	.0291
Cobb's angle (°)	2.0796	4.9970	0	894	1.2520	0.0419

Table 3. Characteristics of the women in the second group (Cobb's angle 5°-10°).

	Characteristics					
	Mean	Max	Min	Count (N)	SD	Standard Error
Age (years)	65	87	41	106	10	1
Height (cm)	161	174	146	106	6	1
Weight(kg)	70	110	42	106	15	1
Total BMDL1-L4 (g/cm²)	.90	1.61	.54	106	.21	.02
Total T-score L1-L4 (SD)	-1.31	5.10	-4.60	106	1.88	.18
Max difference between T-score L1-L4 (SD)	1.6236	5.4000	.3000	106	.9250	.0898
Cobb's angle (°)	6.45	9.99	5	106	1.37	0.13

women (42%) were attributed to the second group with a maximum difference in T-scores >1 SD. We used chi-square test to assess if the women with scoliosis show significantly higher incidence of the maximum difference in the T-scores >1 SD. We found that the maximum difference in the T-scores of the adjacent vertebrae differed significantly between the women with scoliosis and without scoliosis, (p = 0.046). Women with scoliosis showed higher ratio of maximum difference in the T-scores >1 SD to maximum difference in the T-scores ≤1 SD compared to the women without scoliosis. This ratio was approximately 2 (83/42 women) in the group with scoliosis and 1.3 (508/386 women) in the group without scoliosis (Figure 1).

Discussion

The current study showed that the prevalence of lumbar scoliosis was 12.3% using DXA scans. This prevalence was similar to those found in the study of Urrutia *et al.* (12.9%), lower than the prevalence (32%) showed by Makino *et al.*, who assessed lumbar scoliosis in 241 subjects with rheumatoid arthritis, and higher than the prevalence (9.5%) in the study of Pappou *et al.* among 454 subjects.[6,7,18] So, the prevalence of lumbar scoliosis (with range 8.5-32%) varied between the studies, which used DXA scans to diagnose it. This variable results may be caused by the differences between the subjects or by the different methods applied for the assessment of scoliosis. Previous studies analyzing DXA scans to determine the prevalence of lumbar scoliosis in adults used different definitions and values for the Cobb's angle – some studies defined lumbar scoliosis as Cobb's angle >7°,[7] other studies defined it as Cobb's angle ≥11° and Cobb's angle ≥10°.[6,19] Our study is the first one, which defined lumbar scoliosis as Cobb's angle ≥5° according to Chaklin's classification using DXA images. We decided to use Chaklin's classification, firstly, because it is the official one to define scoliosis in Bulgaria and secondly, because we suggested that this mild scoliosis (Cobb's angle 5-10°) could also reflect on the DXA scan results. The strong correlation between the analysis of lumbar scoliosis from DXA scans and the analysis of lumbar scoliosis from plain radiographs in standing position reported in the previous studies motivated us to use DXA images to investigate the prevalence of the lumbar scoliosis for a larger population.[6,7] However, it is pretty known, that lumbar scoliosis could reflect on the interpretation of the DXA results. Scoliosis has been suggested to predispose to osteoporosis, but interestingly degenerative scoliosis could also falsely elevate spinal bone mineral density.[7] In the study of Xu *et al.*, regression analysis showed that BMD was independent risk factor for adult scoliosis and subjects with spine T-score <-2.0 SDs had 1.6-fold higher risk for lumbar scoliosis than those with T-score > -2.0 SDs. The authors of this study recommended screening for adult scoliosis for subjects aged more than 65 years with a spine T-score <-2.0 SDs.[8] Similar to the study of Xu *et al.*, in our study, women with lumbar scoliosis, defined as Cobb's angle >10°, showed lower mean T-score of the lumbar spine (-2.5 SDs) compared to those without scoliosis defined as Cobb's angle < 5°(-1.7 SDs). Although the group with mild scoliosis, defined as Cobb's angle 5-10°, showed lower mean T-score of lumbar spine (-1.3 SDs) than subjects without scoliosis (-1.7 SDs). These results suggest that lumbar scoliosis albeit mild could reflect on the interpretation of DXA results and could lead to diagnostic difficulties. Previous studies reported that BMD should increase from L_1 to L_4 and discrepancy in BMD T-scores by more than 1 SD between the adjacent vertebrae suspects structural abnormalities such as spinal degenerative changes in adults and compression fractures.[1,20] According to the recommendations of the 2015 International Society for Clinical Densitometry's (ISCD) vertebrae should

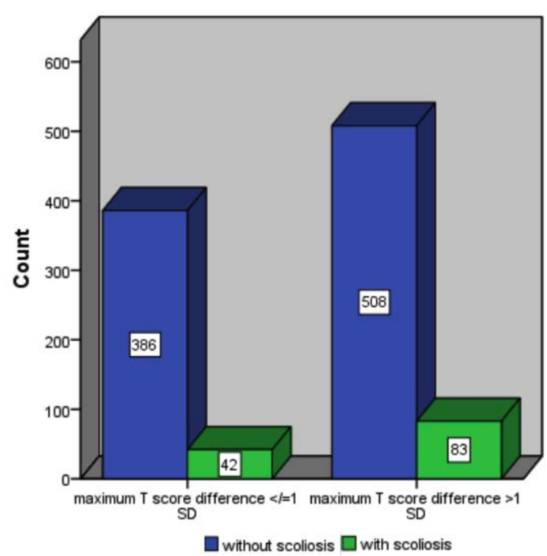

Figure 1. Maximum difference in the T-scores of L_1-L_4 in women with- and without scoliosis.

Table 4. Characteristics of the women with Cobb's angle >10°.

	Characteristics					
	Mean	Max	Min	Count (N)	SD	Standard Error
Age (years)	66	89	43	19	10	2
Height (cm)	159	170	148	19	7	2
Weight(kg)	63	105	41	19	15	3
Total BMDL1-L4 (g/cm^2)	.78	1.10	.60	19	.12	.03
Total T-score L1-L4 (SD)	-2.45	.50	-4.10	19	1.11	.25
Max difference between T-score L1-L4 (SD)	1.6789	5.3000	.3000	19	1.4562	.3341
Cobb's angle (°)	14.327	30.0388	10.0039	19	5.2982	1.2155

be excluded from the analysis if there is a difference between adjacent vertebrae in T-scores >1 SD.[21] Based on these official positions, we evaluated if the subjects with scoliosis showed more often discrepancy in BMD T-scores by more than 1 SD between the adjacent vertebrae compared to the subjects without scoliosis. According to our results women with scoliosis showed significantly higher incidence of discrepancy in BMD T-scores by more than 1 SD compared to women without scoliosis. These results demonstrate that interpretation of DXA scans in subjects with scoliosis is more complicated than in subjects without scoliosis. The differences between the T-scores of the adjacent vertebrae should be taken into account and vertebrae with difference more than 1 SD should be excluded from the analysis.

Conclusions

The increased difference between the T-scores of the vertebrae L_1-L_4 observed in the women with scoliosis in the current study made the interpretation of DXA results more difficult as compared to the women without scoliosis. Thus, DXA results of subjects with scoliosis require more detailed evaluation of the T-scores of each vertebra to make decision about the final diagnosis.

References

1. Harindhanavudhi T, Petryk A, Jones R, et al. Lumbar spine bone mineral density Z-score discrepancies by dual X-ray absorptiometry do not predict vertebral fractures in children. J Investig Med 2018;66:980-5.
2. Jung S, Kim MG, Lee JI. Lumbar Scoliosis in Patients With Breast Cancer: Prevalence and Relationship With Breast Cancer Treatment, Age, Bone Mineral Density, and Body Mass Index 2017;41:868-74.
3. Aebi M. The adult scoliosis. Eur Spine J 2005;14:925-48.
4. Liu G, Peacock M, Eilam O, et al. Effect of osteoarthritis in the lumbar spine and hip on bone mineral density and diagnosis of osteoporosis in elderly men and women. Osteoporos Int 1997;7:564-9.
5. Liu G, Tan JH, Ee G, et al. Morphology and Prevalence Study of Lumbar Scoliosis in 7,075 Multiracial Asian Adults. J Bone Joint Surg Am 2016;98: 1307-12.
6. Urrutia J, Diaz-Ledezma C, Espinosa J, Berven SH. Lumbar scoliosis in postmenopausal women: prevalence and relationship with bone density, age, and body mass index. Spine (Phila Pa 1976) 2011;36:737-40.
7. PappouIP, GirardiFP, SandhuHS, et al. Discordantly high spinal bone mineral density values in patients with adult lumbar scoliosis. Spine (Phila Pa 1976) 2006;31:1614-20.
8. Xu L, Sun X, Huang S, 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.
9. Blake GM, Fogelman I. Role of dual-energy X-ray absorptiometry in the diagnosis and treatment of osteoporosis. J Clin Densitom 2007;10:102-10.
10. Ministry of Health; Bulgarian Societies of Endocrinology and Rheumatology. Recommendations for good clinical practice in osteoporosis. 2013. Available from: https://www.iofbonehealth.org/sites/default/files/PDFs/National%20Guidelines/Guideline_Osteoporosis_Bulgaria_2013_abstract.pdf
11. Ishida K, Aota Y, Mitsugi N, et al. Relationship between bone density and bone metabolism in adolescent idiopathic scoliosis. Scoliosis 2015;10:9.
12. Yip B, Yu F, Wang Z, et al. Prognostic Value of Bone Mineral Density on Curve Progression: A Longitudinal Cohort Study of 513 Girls with Adolescent Idiopathic Scoliosis. Sci Rep 2016;6:39220.
13. Kaleta M, Wronski S. The most common errors in the densitometric diagnosis of osteoporosis. Ortop Traumatol Rehabil 2001;3:338-44.
14. Lewiecki EM, Gordon CM, Baim S, et al. International Society for Clinical Densitometry 2007 Adult and Pediatric Official Positions Bone 2008;43:1115-21.
15. Rand T, Seidl G, Kainberger F, et al. Impact of Spinal Degenerative Changes on the Evaluation of Bone Mineral Density with Dual Energy X-Ray Absorptiometry (DXA). Calcif Tissue Int 1997;60:430-3.
16. Tenne M, McGuigan F, Besjakov J, et al. Degenerative changes at the lumbar spine-implications for bone mineral density measurement in elderly women. Osteoporosis Int 2013;24:1419-28.
17. Kirilov N, Kirilova E, Nikolov N. METHOD OF SIMPLIFIED ASSESSMENT OF THE RISK OF OSTEOPOROSIS IN WOMEN IN MENOPAUSE. Science & Technologies 2000:31-33.
18. Makino T, Kaito T, Fujiwara H, Yonenobu K. Lumbar scoliosis in rheumatoid arthritis: epidemiological research with a DXA cohort. Spine (PhilaPa 1976) 2013;38:E339-43.
19. Kebaish KM, Neubauer PR, Voros GD, et al. Scoliosis in adults aged forty years and older: prevalence and relationship to age, race, and gender. Spine (Phila Pa 1976) 2011;36:731-6.
20. Garg MK, Kharb S. Dual energy X-ray absorptiometry: Pitfalls in measurement and interpretation of bone mineral density. Indian J Endocrinol Metab 2013;17:203-10. d
21. ISCD Official Positions for Adults. 2015. Available from: https://www.iscd.org/official-positions/2015-iscd-official-positions-adult/ (assessed on 28 Sep 2017).