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

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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°.3,4 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.1 Pappou et al. found that Cobb’s angle measured from DXA image strongly correlates with the Cobb’s angle assessed from lumbar radiography.5 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.6 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.7 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.8 On the one hand, it has been suggested that low BMD could be a potential risk factor for the formation of degenerative lumbar scoliosis9,10 and lumbar scoliosis could also reflect on the interpretation of DXA results.9,11-14 However, lumbar scoliosis and osteoporosis are common problems in the elderly population and usually occur simultaneously.15 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.14,16 The purpose of this study is to evaluate the effect of lumbar scoliosis on the DXA scan results.

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/cm² 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 L1-L4,
was 0.865±0.194 g/cm² with range (0.44 g/cm²-2.70 g/cm²), and the average total T-score of L₁-L₄ 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 L₁-L₄ 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 L₁-L₄ and the total T-score of L₁-L₄ 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 L₁-L₄ in the first group was -1.34±0.87 SDs (minimum 0 SDs and maximum 7.3 SDs). 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 L₁-L₄ and total T-score of L₁-L₄ were available for all 106 subjects in the second group and were on average 0.90±0.21 g/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 L₁-L₄ in this group was 1.62±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 maximum 170 cm). Mean weight was 63±15 kg (minimum 41 kg and maximum 105 kg). The average total BMD of L₁-L₄ was 0.78±0.12 g/cm² (minimum 0.60 g/cm² and maximum 1.10 g/cm²) and the average total T-score of L₁-L₄ 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 L₁-L₄ in the third group was 0.869 SDs ± 0.67 SDs (minimum 0.1 SDs and maximum 2.2 SDs). Cobb's angle was on average 14±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 women (42.1%) were attributed to the second group with maximum difference in T-scores 1-4 SD. 0 women (0%) were attributed to the third group with maximum difference in T-scores >4 SD.

Table 1. Data collected from DXA scans.

| Age (years) | Count (N) | Min | Max | Mean | SD |
|-------------|-----------|-----|-----|------|----|
| 40          | 1019      | 89  | 60.84 | 9.501 |
| 40          | 1019      | 89  | 60.84 | 9.501 |
| Height (cm) | 1019      | 140 | 70   | 150.22 | 9.265 |
| Weight (kg) | 1019      | 89  | 50   | 160.22 | 9.265 |
| Total BMDL₁-L₄ (g/cm²) | 1019 | 0.44 | 2.70 | 1.61 | 79.56 |
| Total T-score L₁-L₄ (SD) | 1019 | -5.60 | 14.80 | 1.61 | 1.7517 |
| Max difference between T-score LI-L₄ (SD) | 1019 | 0.000 | 7.3000 | 1.378840 | .8938413 |
| Cobb's angle (°) | 1019 | 0.000 | 30.0388 | 2.762553 | 2.5269054 |

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

| Age (years) | Min | Max | Mean | SD |
|-------------|-----|-----|------|----|
| 60          | 40  | 89  | 60.84 | 9.501 |
| Height (cm) | 160 | 185 | 140  | 10  |
| Weight (kg) | 71  | 165 | 48   | 15  |
| Total BMDL₁-L₄ (g/cm²) | .86 | .270 | .44 | .894 | .19 |
| Total T-score L₁-L₄ (SD) | -1.68 | 14.80 | 5.60 | .894 | 1.74 |
| Max difference between T-score LI-L₄ (SD) | 1.3412 | 7.3000 | 0 | .8701 | .0291 |
| Cobb's angle (°) | 2.0796 | 4.9970 | 0 | .894 | .0419 |

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

| Age (years) | Min | Max | Mean | SD |
|-------------|-----|-----|------|----|
| 65          | 41  | 87  | 106  | 1  |
| Height (cm) | 161 | 174 | 146  | 6  |
| Weight (kg) | 70  | 110 | 42   | 15  |
| Total BMDL₁-L₄ (g/cm²) | .90 | .161 | .54 | .106  |
| Total T-score L₁-L₄ (SD) | -1.31 | 5.10 | 4.60 | 1.88 |
| Max difference between T-score LI-L₄ (SD) | 1.8236 | 5.4000 | .3000 | .9250 | .0898 |
| Cobb's angle (°) | 6.45 | 9.99 | 5 | 106 | 1.37 | .0419 |

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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. (12.3%), 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 Papout 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°,3 other studies defined it as Cobb’s angle ≥11° and Cobb’s angle ≥10°.5,19 Our study is the first one, which defined lumbar scoliosis as Cobb’s angle ≥5° according to 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 L1 to L4 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) vertebral should

**Figure 1. Maximum difference in the T-scores of L1-L4 in women with- and without scoliosis.**

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

| Characteristic                        | 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/cm²)               | .78    | 1.10 | .60  | 19        | .12    | .03            |
| Total T-score L1-L4 (SD)             | -2.45  | -5.00| -4.10| 19        | 1.11   | .25            |
| Max difference between T-score L1-L4| 1.6789 | 5.3000| 3.000| 19        | 1.4562 | .3341          |
| Cobb’s angle (°)                     | 14.327 | 30.038| 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. 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 differences more than 1 SD should be excluded from the analysis.

Conclusions

The increased difference between the T-scores of the vertebrae L1-L4 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.

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