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Title: Effect of neck flexion on measurements of bone mineral density of spine and necessity for applying head positioners during dual-energy X-ray absorptiometry

Running title: Effect of neck flexion

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Effect of neck flexion on measurements of bone mineral density of spine and necessity for applying head positioners during dual-energy X-ray absorptiometry

Abstract:

Rationale: To investigate potential effect of neck flexion on measurements of bone mineral density (BMD) of spine through further reduction of spinal lordosis and necessity for applying head positioners, in addition to leg positioner, during dual energy X ray absorptiometry (DXA).

Methods: Fifty-nine patients without any significant history of spinal disorder were recruited. A bone densitometry scan of spine was performed for all patients using a standard leg positioner in supine position. Then another scan of spine was conducted using a small subnuchal cushion in order to flex neck and thus, to straighten and minimize the lumbar lordosis. Parameters including areas, bone mineral content (BMC), BMD and T- and Z-scores of each lumbar vertebra (L1 to L4) and total spine were extracted in two scans and were then compared.

Results: Mean age of patients were 55.53 (±11.86) and 53 (89.83%) were female and 6 (10.17%) male. A statistically significant difference was found between corresponding values of area, BMD in L4 and total spine. Percentages of change from scan without cushion to with cushion were 1.20% and 0.58% for area of L4 and total spine respectively. Likewise, percentages of change were -0.64% and -0.34% for BMD of L4 and total spine respectively. A change in diagnosis was observed only in one patient from normal to osteopenia.

Conclusion: Use of head positioners to flex neck and thus to minimize lumbar lordosis DXA does not seem to exert a significant effect on the diagnosis and densitometric measurements from clinical standpoint.

Keywords: Bone mineral density; dual energy X ray absorptiometry; lordosis; head positioner.

Introduction:

Dual energy X-ray absorptiometry is currently the unanimously accepted standard method for bone mineral density measurements. The standard procedural guidelines recommend to perform the scanning of the lumbar spine in supine position lying straight without any axial rotation or lateral bending. Furthermore, the scanning field of view should be centered on the spine (L1 to L4) in both dimensions. The curvature or lordosis of the lumbar spine should be minimized, as a major goal to be obtained, by positioning the legs almost perpendicular to the trunk employing a standard positioner supplied by the manufacturer. This strategy makes the lumbar vertebrae lie, as much as possible, at the same level or equidistant from radiation source or detector. Some others may recommend using a head positioner, in addition to leg positioner, for scanning the spine in order to further minimize the lordosis and also maximize the patient comfort during scanning. Taken together, any type of spinal malpositioning may cause the results being over- or underestimated (*1-7*). Spinal deformities including lumbar scoliosis and increased lumbar lordosis and even thoracic kyphosis are important obstacles to achieve the mentioned target for correct positioning. The impact of scoliosis has been investigated in previous studies (*8,9*). Lordosis, specifically, is another issue that causes the results and interpretation of spine densitometry complicated and problematic. This can be of more importance because osteoporosis and spinal deformities (lordosis and scoliosis) are interrelated. A higher prevalence of spinal deformities has been demonstrated in osteoporosis patients compared to non-osteoporosis individuals (*10,11*). Since patients have varying degrees of lordosis, the lumbar vertebrae do not lie horizontally on the scanning table (i.e., each not equally distant from the X ray source and detector), even after applying the positioner beneath the legs. This issue may create uncertainty in the densitometric results of the lumbar vertebrae. One way to overcome this problem is the minimization of lumbar lordosis to highest possible level by flexing the neck. By means of a subnuchal cushion, the lumbar vertebrae lie as much at the same level on the scanning table as possible as well as position more consistently from scan to scan. However, the potential effect and also the degree to which this issue may influence the BMD, T- and Z-scores and thus the final diagnosis, are less known and scarcely investigated. For this reason, to investigate the potential effect of such factor, we aimed to perform the scans with the standard method (i.e., sole use of leg positioner) and then to repeat the scan with concomitant use of leg and head positioners by applying a small cushion below the neck.

Materials and Methods:

Fifty-nine patients, 53 (89.83%) female and 6 (10.17%) male, without any history of cervical or lumbar spinal disorder, including cervical spondylosis, significant lumbar lordosis and previous operative procedures or prior trauma were consecutively selected and then included in the study after obtaining a signature of written informed consent. Patients aged below 18 and above 80 are excluded because of unavailability of corresponding database for comparison to generate statistical results. A bone densitometry scan of the spine was performed for all patients based on standard method, i.e., using a standard positioner supplied by the manufacturer beneath the legs in supine position to reduce the lordosis of the lumbar spine, as shown in Fig. 1A. Then, without significant changing the patient's position, another scan of the lumbar spine was conducted using a small cushion (8 Cm high from the surface of the scanning table) below the neck in order to flex the neck and thus, to straighten and minimize the normal curvature of the lumbar spine (Fig. 1B). After that, the scan of the hip region is performed according to standard procedural protocol (from proximal femur in internal rotation by means of strapping the foot of index limb to the standard positioner). A HOLOGIC® QDR® series densitometry scanner with a standard manufacturer-designed leg positioner was used for all scans. The scans with significant focal abnormalities in the vertebrae, from L1 to L4 were excluded from the study. All images were analyzed automatically, with minimum interaction by the operator, using the standard software provided by the manufacturer. In case of inaccurate placement of regions of interest and errors in bone mapping, manual corrections were implemented. Bone mineral density results, including the areas in cm^2, the BMC in gr, and the BMD in gr/cm^2, T- and Z-scores of each lumbar vertebra (L1 to L4) and total spine were extracted in two scans (before and after using a subnuchal cushion) and also for the proximal femur, for each patient. The corresponding data were compared with paired-sample t test using the SPSS software for statistical analysis. Significance level is set at 0.05. For making the diagnosis, based on mineral density results of lumbar spine and proximal femur (neck and total area), the World Health

Organization (WHO) classification is used for menopausal women and men over 50 (as T-score equal or more than -1 is normal, between -1 and -2.5 is osteopenia and equal or less than -2.5 is osteoporosis) and International Society for Clinical Densitometry (ISCD) classification for premenopausal women and men under 50 (-2 or less as below the expected range for age and higher than -2 as within the expected range for age). Changes in the diagnosis are expressed in numbers and percentages. And then the diagnoses in both scans were tested for agreement to derive kappa coefficient. The study was approved by the School of Medicine Ethics committee.

Results:

Basic demographic characteristics of the 59 individuals included in the study as well as their densitometric data of the femoral neck and total femur are presented in Table 1. The mean and standard deviation of area, BMD derived for each vertebra from L1 to L4 and area, BMC, BMD, T- and Z-scores for total spine in two scans for each patient are summarized in Table 2. The error bar plots of area, BMC and BMD of L1 to L4 is presented in Fig. 2. As can be seen, a gradual increase in area, BMC and BMD is seen from L1 to L4. A statistically significant difference was found between corresponding values of area, BMD and T-score in L4 and total spine. The difference of BMC in total spine in both scans was not statistically significant. In L4 and total spine, the area was higher in scan performed with cushion and conversely, the BMD was higher in the scan without cushion. The percentages of change from scan without cushion to with cushion were 1.20% and 0.58% for area of L4 and total spine respectively. Likewise, percentages of change were -0.64% and -0.34% for BMD of L4 and total spine respectively. In the scans without cushion, there were 11 (18.6%) normal, 19 (32.2%) osteopenia, 19 (32.2%) osteoporosis, 9 (15.3%) within the expected range for age and 1 (1.7%) below the expected range for age. In the scans with cushion, there were 10 (16.9%) normal, 20 (33.9%) osteopenia, 19 (32.2%) osteoporosis, 9 (15.3%) within the expected range for age and 1 (1.7%) below the expected range for age. A change in the diagnosis was observed only in one patient (1.7%) from normal to osteopenia (agreement kappa coefficient of 0.977).

Discussion:

Technical issues exert an important effect on bone mineral densitometric measurements. Proper and consistent positioning is one of such factors. This factor is of high importance not only for obtaining results with higher accuracy, but also to make serial scans comparable and thus suitable for decision making. As mentioned before, the spine, because of higher proportion of trabecular tissue in its composition, is an essential and indispensable part of densitometric measurements. But since there is a variable degree of lordosis, strategies should be adopted to flatten the lumbar spine as much as possible. Otherwise, intra- or inter-patient uncertainty may arise. Using a leg positioner to flex the hip joint up to 90 degrees is a routine part of the procedure. But in most of the patients some degree of lordosis may persist. In such situations, flexing the neck using a cushion below the neck may be helpful to make the spine lie flattened on the scanning table, the effect of which is the intention of this study. Some manufacturers may supply a dedicated head positioner to routinely position the head during scanning. But the effect of this task is uncertain and has been less investigated. We applied a cushion with an approximate height of 8 Cm above the level of scanning table. This degree of neck flexion seems to be sufficient to reduce the remaining lordosis after hip flexion. The results showed a statistically significant difference in the area and BMD of the L4 vertebra and also of the total spine. No difference in the BMC was found and this implies that the changes in BMD could be as a function of area. But the changes were remarkably low in absolute values. Of 59 individuals recruited in the study, in only one, a one-level change in diagnosis (i.e., from normal to osteopenia) was observed. This amount of potential error is considerably lower than those from spinal malpositioning and scoliosis (*2,3,9*). In one study by Pavlovic et al (*8*), the BMD of the spine was measured in presence of thoracic kyphosis and lumbar lordosis. It was concluded that as the amount of curvature increase in the thoracic or lumbar spine, the value of BMD decreases. However, the correlation was weak to moderate between measured curvature and spine BMD and these findings were the opposite of ours.

Moreover, the concept of least significant change should also be taken into account when comparing serial scans as those in our study. The amount of such parameter is variable among different centers, but an overall amount of 3% to 4% is accepted and rates of changes below such values cannot be considered statistically significant (*12,13*). And this amount is much higher compared to changes in the BMD of the spine in this study. All above findings may not lay a solid foundation to recommend the routine use of head positioners. However, its effect in the patient comfort by holding the arms raised during the scanning may be beneficial.

In the present study, we practiced methods to reduce lumbar lordosis in patients with normal lordosis or at least without significant abnormality, but the degree of lordosis, whether qualitatively or quantitatively, was not assessed or measured before the first and second scans, although there exist methods for measurement of spinal curvatures (*14*). The flexibility or rigidity of the perispinal soft tissues and therefore lordosis varies among patients. The pool of patients with near flattened spine after hip flexion, even without neck flexion, may diminish the effect size and thus this issue should be taken into account. However, we selected a cushion with a fixed height of 8 cm, in other words, not being tailored to the patients' height. This amount of neck flexion attained can be generally considered sufficient to decrease the lordosis.

Conclusion:

Use of head positioners to flex neck and thus to minimize lumbar lordosis during dual energy X-ray absorptiometry does not seem to exert a significant effect on the diagnosis and densitometric measurements from clinical standpoint.

Conflict of interest and financial disclosure:

Mohsen Qutbi, Sajad Ghanbari, Mehdi Soltanshahi, Saba Karami Gorzi, Yaser Shiravand and Shahla Ranji declare that they have no conflict of interest to disclose. No financial support or fund was assigned to this project.

Ethical approval:

The study was approved by the Ethics committee of the School of Medicine, Shahid Beheshti University of Medical Sciences. The ethics code is (IR.SBMU.MSP.REC.1398.324).

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Figures:

FIGURE 1: A, the patient is positioned on the scanning table with a leg positioner beneath the legs. B, without changing the position of the patient, a cushion is laid below the neck to achieve sufficient neck flexion.

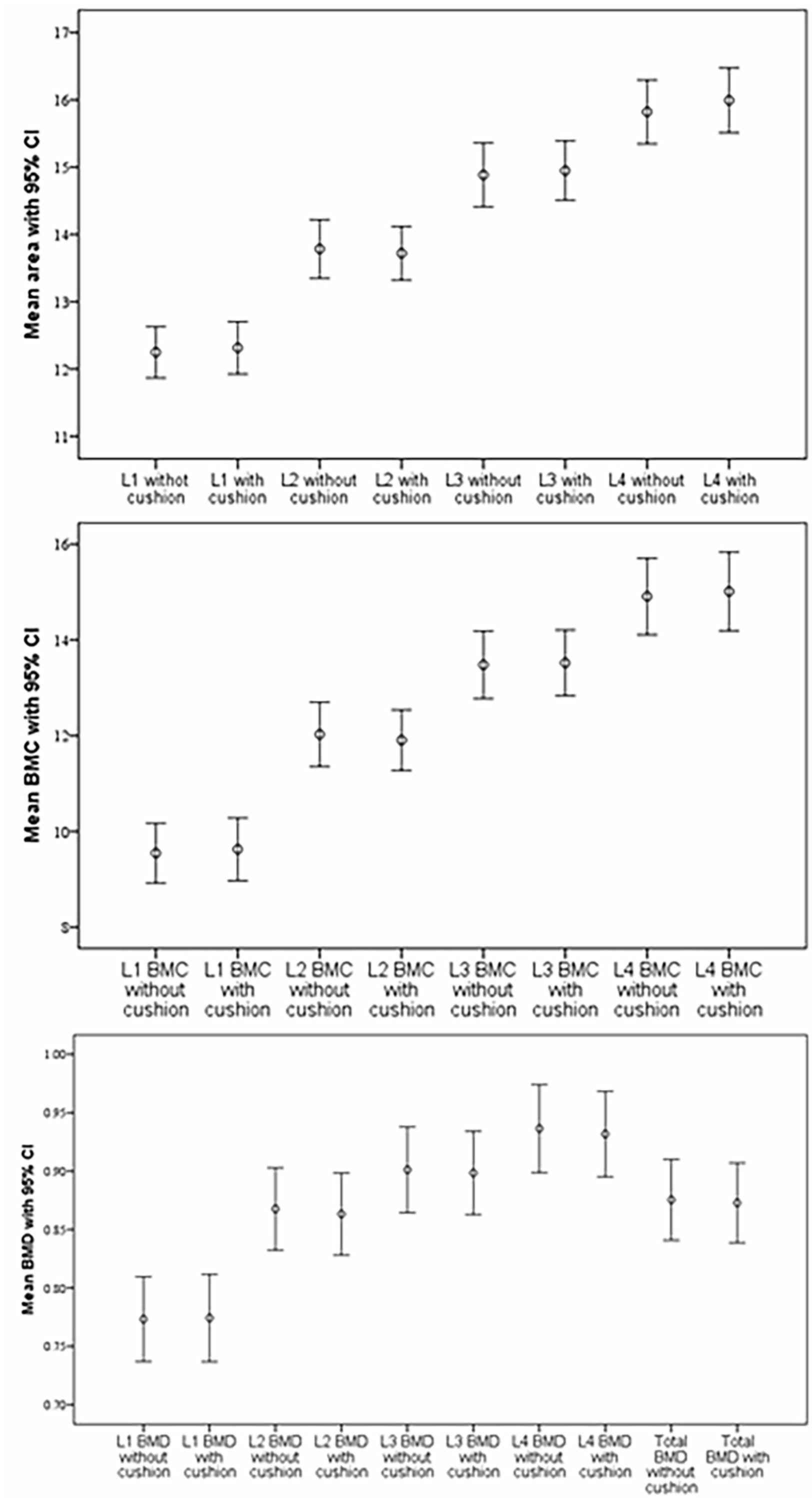

FIGURE 2: Error bar plots of area (top left), BMC (top right) and BMD (bottom). The values of area, BMC and BMD is gradually increasing from L1 to L4.

Table 1: Basic characteristic data of the patients

Description	Value (n=59)
Age	
Female	55.77 (±10.41)[a]
Male	53.33 (±22.29)
Total	55.53 (±11.86)
Range	18-76
Gender (female : male)	53 (89.83%) : 6 (10.17%)[b]
Weight	66.15 (±10.01)
Height	159.83 (±6.88)
BMI[c]	26.00 (±4.23)
Status	
Premenopausal female	8 (13.6%)
Menopausal female	45 (76.3%)
Male under 50	2 (3.4%)
Male over 50	4 (6.8%)
Femoral neck	
Area	4.62 (±0.47)
BMD	0.701 (±0.12)
T-score	-1.4 (±1.0)
Z-score	-0.3 (±1.1)
Total femur	
Area	32.87 (±3.84)
BMD	0.818 (±0.11)
T-score	-1.1 (±0.9)
Z-score	-0.3 (±1.0)

[a]: mean (±SD); [b]: number (percentage); [c]: Body Mass Index.

Table 2: Values of densitometric measurements of total spine and L1-L4 vertebrae

Description	Results				P value
(of spine)	Without cushion	With cushion	Mean difference	CI 95%	
Area					
L1	12.24 (±1.49)	12.32 (±1.52)	-0.08 (±0.48)	-0.20 – 0.05	0.214
L2	13.80 (±1.69)	13.74 (±1.54)	0.06 (±0.51)	-0.07 – 0.19	0.355
L3	14.88 (±1.86)	14.97 (±1.71)	-0.08 (±0.42)	-0.19 – 0.03	0.135
L4	15.80 (±1.84)	15.99 (±1.88)	-0.19 (±0.54)	-0.33 – -0.05	0.009*
Total	56.73 (±6.37)	57.06 (±6.14)	-0.33 (±0.78)	-0.53 – -0.13	0.002*
BMC					
Total	49.96 (±10.22)	50.09 (±10.16)	-0.13 (±0.87)	-0.36 – 0.09	0.245
BMD					
L1	0.774 (±0.14)	0.774 (±0.15)	0.000 (±0.02)	-0.005 – 0.005	0.906
L2	0.868 (±0.14)	0.864 (±0.14)	0.004 (±0.02)	-0.001 – 0.009	0.108
L3	0.905 (±0.14)	0.902 (±0.14)	0.003 (±0.02)	-0.001 – 0.007	0.189
L4	0.940 (±0.14)	0.935 (±0.14)	0.006 (±0.02)	0.001 – 0.010	0.011*
Total	0.878 (±0.13)	0.875 (±0.13)	0.003 (±0.01)	0.001 – 0.006	0.018*
T-score					
Total	-1.57 (±1.2)	-1.60 (±1.2)	0.03 (±0.1)	0.00 – 0.05	0.046*
Z-score					
Total	-0.42 (±1.3)	-0.45 (±1.3)	0.03 (±0.1)	-0.00 – 0.05	0.096