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Original Article

Hylonome

The impact of bone mineral density on the degree of curvature of the lumbar spine

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Abstract

Objective: The prevailing perception is that one of the causes of postural deformities is osteoporosis. Nonetheless, studies of the correlation between bone mineral density (BMD) and spinal curvatures have produced contradictory results. This study was undertaken in order to determine whether (BMD) is associated with the curvature of the lumbar spine. **Methods:** 105 post-menopausal women, aged 45-76 years (average= 57.3 years), were examined. All the participants underwent DXA scanning and spinal radiography using the same equipment and techniques. Lumbar curvatures were measured using the Cobb method. Subjects were divided according to their T- score into osteoporosis patients (n=54) and controls (n=51). Statistical analysis was performed using one way ANOVA, Mann-Whitney as well as Pearson and Spearman rank correlations. **Results:** There were no statistically significant correlations between BMD and lumbar curvature angles either in the total sample or in either group individually. Furthermore, these angles were not significantly different between patients with osteoporosis and controls. **Conclusions:** The reduction in BMD and the alteration of the lumbar curvature that are observed in elderly individuals are concurrent but not related phenomena. The findings of this study contradict the claim that reduced bone mineral density is the cause of postural deformities.

Keywords: Lumbar Lordosis, Osteoporosis, Bone Mineral Density

Introduction

Postural deformities, a common characteristic of elderly patients, are often attributed to aging and osteoporosis[1-3]. These deformities consist mainly of upper back slouching, low back rounding, a stepwise decline in height, and a protuberant abdomen[4]. The loss of the normal sagittal configuration induces abnormal stress on the paravertebral structures and can cause chronic back pain, which develops on standing, walking and other daily activities[5].

The prevailing perception is that one of the causes of these deformities is osteoporosis. However, investigations of the association between bone mass and spinal curvatures have produced ambiguous results. Specifically, while some studies have shown a correlation between bone mineral density (BMD) and the magnitude of spinal curvatures[4,6-9], several others couldn't establish such a relationship[2,10-13]. Ultimately, based on the available evidence, it is still open to doubt whether bone mass *per se* has any effect on sagittal spinal morphology.

The claim that the geometrical features of bones are related to their mineral density has been tested and validated in the hip joint[14,15]. It would seem folly to attempt to correlate hip shape to lumbar BMD. And yet, most investigators have attempted to determine the relation of bone mass with spinal curvature by measuring the former in the lumbar spine or hip and the latter in the thoracic spine. The rationale of these later studies is that in some cases there is no obvious vertebral fracture and the question is whether multiple microscopic endplate or trabecular osteoporotic fractures can explain the kyphotic deformation. One would expect that if a relationship does exist, it would be revealed should the curve be studied in relation to the mineral density of its component vertebrae. By convention, DXA scanning takes place in the lumbar spine. Hence the curvature of the part of the spine for which bone density data are available is lordosis, rather than kyphosis.

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	TOTAL n=105	CONTROL n=51	OSTEOPOROSIS n=54	SIGNIFICANCE (p value)
AGE (years)	57.3 [6.5]	54.6 [6.4]	60.3 [6.2]	p =0.127 NS
BMI (kg/m^2)	29.2 [5.5]	30.2 [4.4]	28.1 [3.9]	p =0.246 NS
L1 – L5 (deg)	37.6 [13.2]	38.3 [11.6]	41.1 [11.5]	p =0.686 NS
L1 – S1 (deg)	52.7 [12.9]	52 [12.5]	53.4 [12.5]	p =0.903 NS
L5 – S1 (deg)	14.8 [7.1]	14.8 [6.1]	14.5 [5.4]	p =0.605 NS

Values outside parentheses represent means, while values inside parentheses are standard deviations. The comparison of the total sample with each group as well as between groups (pairwise comparisons) also did not demonstrate statistically significant differences. BMI = Body Mass Index, NS = non significant.

Table 1. Demographic characteristics of the sample.

To recapitulate, it has been proposed that the curvature of the spine is affected by its BMD. If this were true, then a correlation must exist between the curvature and BMD, when both these parameters are measured at the same site. The preceding statement constitutes the primary hypothesis of this study. It also follows that patients with osteoporosis and non-osteoporotic subjects will have different curvatures. This is the secondary hypothesis that the present study tests.

Methods

The design of the study was cross-sectional and observational. Subjects were selected from a group of 524 consecutive patients that were examined over a period of 6 months in the Outpatients Department of the Orthopaedics Clinic, University Hospital of Heraklion, Crete. All patients underwent DXA scanning with the same equipment (QDR – 2000, Hologic, Waltham, MA). Additionally, they were all referred for anteroposterior and lateral radiographic examination of the thoracic and lumbar spine in the standing position, where the same equipment and procedure were used for every subject. These radiographs are an important part of each patient's initial evaluation. They constitute baseline imaging studies for comparison with any future radiographs. It is stressed that subjects were not unnecessarily exposed to radiation. All patients were asked to sign a disclaimer that the results of their examination may be used in clinical studies. The study protocol was approved by the ethics committee of the University of Crete, Faculty of Medicine.

Patients with secondary osteoporosis and possibly confounding spinal conditions ought to be excluded from the study. Exclusion criteria therefore were history of metabolic or endocrine disease (including history of premature menopause) (n=95); use of drugs that affect BMD[16] (n=73); evidence of vertebral fracture (n=68), radiographic osteoarthritis (spondylosis)[17] (n=59); congenital spinal disorders ((hemivertebra, sacralization or lumbarization, Scheuermann kyphosis etc) (n=39); spondylolysis (n=18); spondylolisthesis (n=10); scoliosis (n=11); or any other disorder that might interfere with our study (alcohol abuse, history of inflammatory arthropathy, trauma, surgery etc) (n=13). A further 33 patients were excluded due to poor quality of their spinal radiographs. All radiographs were examined by two observers (MP and PK), independently, for the presence of conditions described in the exclusion criteria. Disagreement was resolved by consensus.

AGE			
	TOTAL	Control	Osteoporosis
L1-L5	.915	.537	.701
L1-S1	.513	.678	.685
L5-S1	.149	.620	.254
BMI			
	TOTAL	Control	Osteoporosis
L1-L5	.161	.394	.076
L1-S1	.552	.219	.148
L5-S1	.514	.507	.975

Correlations (p-values) of lordosis angles with age and BMI for the total sample and for each group separately. None of these correlations reached statistical significance.

Table 2. Correlations of lordosis angles with age and BMI.

The original pool of patients from which suitable subjects were selected contained 524 individuals. By applying the strict exclusion criteria described above, only 105 patients were qualified for inclusion. The final sample comprised exclusively of postmenopausal women, aged 45-76 years (mean=57.3). It has been established that spinal curves correlate with age and sex[18-21], and that bone mass is influenced by age, sex and menopause[22]. In view of that, the homogeneity of the final sample essentially eliminates these variables.

Lumbar lateral radiographs were digitized and measurements were made using Cobb's method with the assistance of a computer program (OsiriX Medical Image software, available at http://www.osirix-viewer.com). The use of computers for lumbar lordosis measurements has been shown to be at least equal,

	TOTAL		CONTROL		OSTEOPOROSIS	
	MEAN [SD]	**RANGE**	**MEAN [SD]**	**RANGE**	**MEAN [SD]**	**RANGE**
AGE	57.3 [6.5]	41-76	54.6 [6.2]	41-70	60.3 [6.2]	45-76
BMI	29.2 [5.5]	20.4-34.2	30.2 [4.4]	22-34.2	28.1 [3.9]	20.4-32.3
BMD L1	.74 [.14]	.44-1.07	.83 [.10]	.69-1.02	.65 [.08]	.52-.86
BMD L2	.83 [.15]	.49-1.25	.95 [.12]	.80-1.25	.72 [.08]	.53-.86
BMD L3	.89 [.15]	.57-1.24	.98 [.14]	.81-1.24	.79 [.08]	.66-.99
BMD L4	.92 [.16]	.52-1.31	1.04 [.15]	.86-1.31	.81 [.08]	.59-.95
BMD L1-L4	.85 [.14]	.51-1.17	.96 [.12]	.82-1.17	.75 [.07]	.62-.90
T score L1	-1.66 [1.28]	-4.43-1.29	-.88 [.95]	-2.12-.90	-2.54 [.74]	-3.72-(-.64)
T score L2	-1.81 [1.40]	-4.93-1.99	-.74 [1.12]	-2.04-1.99	-2.79 [.74]	-4.53-(-1.56)
T score L3	-1.81 [1.34]	-4.64-1.42	-.91 [1.23]	-2.46-1.42	-2.68 [.76]	-3.90-(-.85)
T score L4	-1.75 [1.43]	-5.39-1.75	-.66 [1.38]	-2.37-1.75	-2.79 [.73]	-4.82-(-1.56)
T score L1-L4	-1.77 [1.29]	-4.89-1.15	-.80 [1.09]	-2.03-1.15	-2.70 [.62]	-3.85-(-1.34)
angle L1-L5	37.6 [13.2]	4.0-70.0	38.3 [11.6]	9.0-67.0	41.1 [11.5]	4.5-70.0
angle L1-S1	52.7 [12.7]	21.0-84.5	52 [12.50]	21.0-83.0	53.4 [12.5]	22.5-84.0
angle L5-S1	14.8 [7.1]	2.50-35.0	14.8 [6.1]	2.5-30.0	14.5 [5.4]	3.0-28.0

Means, standard deviations and value range of measured characteristics. Similarly to the previous table, values outside parentheses represent means, while values inside parentheses are standard deviations.

Table 3. Means, standard deviations and value range of measured characteristics.

if not better, to the manual method[23-25]. Measurements were made from the top of L_1 to the bottom of L_5 as well as from the top of L_1 to the top of S_1. In addition, since several investigators have shown 50% to 75% of the total lordosis between L_1 and S_1 to be located at the bottom two motion segments[26-31], the angle between the bottom of L_5 to the top of S_1 was also measured.

The primary hypothesis of the present study is that spinal curvature and BMD are associated. Therefore, the correlation between these parameters was investigated in the entire sample. The secondary hypothesis is that patients with osteoporosis and non-osteoporotic subjects will have different spinal curvatures. Patients were thus divided into two groups based on their BMD. Those with T- score ≤-2.5 SD were classified in the osteoporosis group, while those with higher values were classified in the control group. Concerning the secondary hypothesis, in order to have a power of 80% to detect a difference of as little as 10 degrees at the 0.05 level of significance assuming a standard deviation of 15 degrees, a priori power analysis showed that 35 women would be needed in each group. The increased enrolment augmented the power of the study. Statistical analysis was hence performed for the total sample as well as each group separately. The comparison of variables among the groups was performed using the one factor ANOVA model with no repeated measurements. For pairwise multiple comparisons, Mann-Whitney test was used. Pearson and Spearman rank correlation was used to correlate continuous data. All tests are two sided with p=0.05 considered significant. Analysis was performed using SPSS for Windows, Rel. 13.00. SPSS Inc. Chicago, IL.

Results

Osteoporosis was diagnosed in 54 patients, while the remaining 51 formed the control group. Age and body mass index (BMI) were matched either in overall comparison or comparing the total sample and the groups in pairs. Lordosis angles were also not statistically different in overall or pairwise comparisons. This signifies that the curvature of the lumbar spine was not different between patients with osteoporosis and controls. These comparisons are displayed in Table 1. Age and BMI were also not correlated with lordosis angles, as shown in Table 2. The means, ranges and standard deviations of BMD, T- score and lordosis angles for the total sample as well as each group separately are shown in Table 3. The correlations between BMD and lordosis angles for the total sample as well as each group individually are presented in Table 4. None of the correlations between BMD and the angles of lumbar curvature reached statistical significance.

Discussion

The present study demonstrates that the BMD is not significantly correlated with the curvature of the lumbar spine. In addition, lumbar lordosis wasn't significantly different between patients with osteoporosis and controls. These findings contradict the assumption that the reduction in bone mass has an effect on the postural deformities observed in elderly individuals. An explanation for this lack of association is that the two phenomena take place

TOTAL			
	L1-L5	**L1-S1**	**L5-S1**
BMD L1	.170	.258	.667
BMD L2	.388	.497	.644
BMD L3	.250	.694	.979
BMD L4	.053	.178	.837
BMD L1-L4	.160	.359	.801
BMD NECK	.454	.252	.377
BMD TROCHANTER	.263	.420	.702
BMD INTER	.146	.119	.565
BMD TOTAL	.215	.207	.651
OSTEOPOROSIS			
	L1-L5	**L1-S1**	**L5-S1**
BMD L1	.977	.685	.587
BMD L2	.814	.802	.950
BMD L3	.858	.453	.563
BMD L4	.737	.887	.796
BMD L1-L4	.984	.813	.835
BMD NECK	.372	.798	.308
BMD TROCHANTER	.903	.788	.526
BMD INTER	.722	.588	.483
BMD TOTAL	.711	.818	.745
CONTROL			
	L1-L5	**L1-S1**	**L5-S1**
BMD L1	.797	.878	.136
BMD L2	.594	.740	.293
BMD L3	.413	.749	.248
BMD L4	.822	.953	.548
BMD L1-L4	.604	.854	.282
BMD NECK	.896	.605	.105
BMD TROCHANTER	.480	.801	.224
BMD INTER	.429	.701	.236
BMD TOTAL	.514	.724	.272

Correlations (p-values) of lordosis angles with bone mineral density (BMD) for the total sample and for each group separately. None of these correlations reached statistical significance.

Table 4. Correlations of lordosis angles with bone mineral density.

contemporaneously as age advances but apparently, based on these findings, they are independent, with no relationship between them. Another explanation is that vertebrae are essentially non- elastic bodies. As such, they do not deform unless they fail mechanically and fracture[32]. Macroscopically evident fractures occur when the mineral density is reduced below a critical value. As a result of the friable nature of vertebrae, when no obvious fractures can be seen then the shape of each vertebra and accordingly, the configuration of the whole spine, do not change appreciably.

The methodology applied in this study excels on several points in comparison to previous similar investigations. Specifically, confounding factors such as vertebral fractures, use of drugs that affect BMD, spinal degenerative disease and others have been eliminated, with the use of strict exclusion criteria. Cobb's technique, the gold standard in determining spinal curvatures was employed, and more than a single angle was measured. The same equipment and techniques were used to perform the examinations for the entire sample. When human factor became an issue in evaluations or interpretations, these were performed by two independent observers. The homogeneity of the sample in char-

acteristics such as age, sex, hormonal status and, as it happened, body mass, means that these features didn't constitute uncontrolled variables. Finally, the relationship of spinal curvature with BMD was examined in the same part of the spine. Consequently the association that was investigated is the most relevant to the study question. A limitation of the study is that a cross-sectional rather than a longitudinal design was used. However, to prospectively observe patients with or at risk of osteoporosis without intervening would have been ethically dubious. Therefore the shortcomings of a cross sectional design had to be accepted in order to maintain the observational character of the study. Another limitation is that only anteroposterior DXA scanning was available to use, when it has been shown that lateral scanning may be superior in the lumbar spine[33]. It could also be argued that, concerning the secondary hypothesis, the control group includes subjects with osteopenia as well as with normal bone mass. Nevertheless, a clear cut-off value was used to separate patients from controls, which constitutes sound practice.

As aforementioned, the association between BMD and spinal curvatures has also been investigated in previous studies, which have produced conflicting results. Numerous investigations measure thoracic kyphosis and examine its association with lumbar or femoral BMD[2,4,6,7,11]. The findings of any such investigation don't address the core question, that is, whether the curve is affected by the mineral density of its building blocks. Some of these studies use methods of curvature measurement other than Cobb's method, such as goniometers[2], flexicurves[4,6], curviscopes[9,10], spinal pantographs[12] and others[8]. Although these instruments may be quite reliable, the superiority of Cobb's method over all others is well established[24] and this is why it has remained the gold standard in the course of decades. In the study by Sinaki et al[13] the vertebra where kyphosis turns into lordosis is called the interference vertebrae and curves were measured from and up to that point. By applying this method the same start and end points were not used in all measurements to determine spinal curvatures. This process certainly limits reproducibility and possibly also validity. Finally, in some of these studies patients with vertebral fractures were included in the sample[4,6,9-11]. Such patients must be excluded from any such study, as they can only compromise the results.

The results of this study lead to the conclusion that bone mass reduction *per se* does not entail an alteration of the curvature of the lumbar spine. Research so far has suggested that postural deformities may be influenced by intervertebral disk degeneration[11,34], weakening of back extensor muscles[2,6,13] and the presence of vertebral compression fractures[13]. However, the relationship between these factors has only been investigated in cross-sectional studies, from which causality can not be inferred. The literature lacks a prospective, longitudinal, controlled study that would categorically identify the causes of postural deformities in the elderly.

Conclusion

In this observational, cross sectional study, no statistically significant association was found between BMD and spinal curvatures, when both were measured in the same area of the spine. This holds true whether the entire sample was examined or when it was divided into osteoporosis patients and controls. Additionally, patients with osteoporosis and controls did not have significantly different lumbar spine curves. Age related bone mass reduction and the progression of postural deformities are evidently concurrent but unrelated processes. These findings contradict the claim that reduced BMD contributes to the development of postural deformities.

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