Lumbar lordosis in osteoporosis and in osteoarthritis

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Abstract The curvature of the lumbar spine and the risk of developing either osteoporosis (OP) or osteoarthritis (OA) are influenced by many common factors. The aim of this study is to determine whether lumbar lordosis is different between patients with either disease and healthy persons. A cross-sectional, blinded, controlled design was implemented. One hundred and twelve postmenopausal women were evaluated for bone mineral density as well as undergoing spinal radiography. Lordosis measurement was performed with Cobb's method. The sample was divided in four groups: patients with OP ($n = 34$, $L1-L5 = 40.7^\circ$, $L1-S1 = 54.1^\circ$), patients with OA ($n = 29$, $L1-L5 = 38^\circ$, $L1-S1 = 52.3^\circ$), patients with both diseases ($n = 20$, $L1-L5 = 41.8^\circ$, $L1-S1 = 52.3^\circ$) and controls ($n = 29$, $L1-L5 = 38.6^\circ$, $L1-S1 = 51.8^\circ$). For all participants age, height, weight, body mass index, physical activity level and basal metabolic rate were measured and recorded. The results revealed that although the four groups have significant constitutional differences, lumbar lordosis was comparable between them. The reasons for the lack of association are discussed.

Keywords Lumbar lordosis · Osteoarthritis · Osteoporosis

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Introduction

The incidence of osteoarthritis (OA) and osteoporosis (OP) is different in anthropometrically dissimilar populations. Patients with osteoarthritis have more weight, bigger body mass index (BMI), higher body fat percentage, darker skin, more muscle mass and greater muscular strength than patients with osteoporosis [6–8, 40]. Another factor that influences the development of either disease is physical activity. Decreased physical activity is a well established risk factor for the development of osteoporosis [42, 43]. On the other hand, osteoarthritis is associated with increased levels of physical activity, occurring usually in occupational settings [2, 32]. Common features between these populations are advanced age and, as a rule, female sex. However, the peak incidence of osteoarthritis occurs earlier than that of osteoporosis; in other words patients with osteoarthritis tend to be younger than the ones with osteoporosis. Moreover, the correlation between sex and osteoporosis is stronger than that between sex and osteoarthritis.

The above-mentioned characteristics also influence the degree of the sagittal curvature of the lumbar spine. Lumbar lordosis displays a broad range of normal values depending on the anthropometric traits of the measured individual. The curve increases with age [1, 10, 19, 20, 24, 27, 41, 44, 46, 48], body mass [21, 22, 38, 39, 45] and physical activity [3, 21, 48]. Women have increased lordosis in comparison to men [1, 10, 11, 18, 20–22, 28, 39, 41, 47]. Finally, a relationship between race and the degree of lordosis has been shown to exist [9, 25, 39].

Taking these facts into consideration, it becomes evident that lumbar lordosis and the risk of developing either osteoporosis or osteoarthritis are correlated with many common factors, as presented in Table 1. Accordingly, the potential

Table 1 Comparison of factors affecting disease development and lumbar curvature configuration

Risk factors for the development of osteoporosis [43]	Risk factors for the development of osteoarthritis [2, 32]	Factors influencing the curvature of the lumbar spine [1, 3, 9–11, 18–22, 24, 25, 27, 28, 38–41, 44–48]
Age	Age	Age
Sex	Sex	Sex
Race	Race	Race
Genetic predisposition	Genetic predisposition	Genetic predisposition
Body mass	Body mass	Body mass
Physical activity	Physical activity	Physical activity
Drugs	Trauma	Trauma
Smoking	Birth defects	Spinal diseases (spondylolysis, spondylolisthesis etc)
Alcohol abuse	History of inflammatory arthropathy	
Metabolic–endocrine diseases	Metabolic–endocrine diseases	
Premature menopause		

The factors from age to physical activity concern the primary forms of the diseases and are shared. The effect that each factor has may be different, i.e., as age increases, so does the risk of developing either disease. Conversely, as body mass increases, the risk of developing osteoporosis drops while the risk of developing osteoarthritis rises

of an association between lumbar lordosis and the presence of either disease emerges. It seems conceivable that the degree of curvature of the lumbar spine could perhaps indicate what the overall effect of those common factors is. Even if the curvature by itself does not influence disease onset or progression, it might still express the common outcome of different factors that are determinants for each disease. In that case, the magnitude of lumbar lordosis would reflect the risk of being afflicted with either one of these conditions. Since normal lordosis displays a wide spectrum of values, it is possible that patients with osteoarthritis have a different range than those with osteoporosis.

Consequently, the following hypothesis was formulated: the curvature of the lumbar spine and the risk of developing either osteoporosis or osteoarthritis are correlated with many common factors. The null hypothesis is that a correlation exists between lumbar lordosis and the presence of either disease. The secondary hypothesis was that lumbar lordosis would differ between patients with either osteoporosis and/or osteoarthritis and patients without these diseases. The aim of this study is to investigate whether such an association or whether such differences exist.

Materials and methods

Subjects

Suitable subjects were singled out from the records of a study of the prevalence of vertebral osteoporotic fractures in the population. Participants in that study are evaluated at the University Hospital of Heraklion, Crete. All patients

undergo DEXA scanning at the lumbar spine and hip with the same equipment (QDR–2000, Hologic, Waltham, MA), in order to confirm or exclude the presence of osteoporosis. Additionally, they all have anteroposterior and lateral X-rays of the thoracic and lumbar spine taken in the standing position, using the same procedure and equipment.

By selecting our sample from this group of individuals, it became possible to avoid the need to expose any further people to radiation. In addition, the population group that participated in the study in question was exceptionally homogeneous, as it comprised almost exclusively of women of postmenopausal age. Therefore, a sample was available in which parameters that influence body posture such as age and sex (as described in the “[Introduction](#)”) were not variable, and furthermore the age range was in the period where osteoarthritis and osteoporosis obtain their maximum frequency [16, 23, 43].

Individuals with secondary osteoporosis or osteoarthritis as well as those whose lumbar curvature might have been altered from disease or iatrogenic intervention were excluded from the study. Exclusion criteria were history of metabolic or endocrine disease (including history of premature menopause); use of drugs that affect bone mineral density (BMD); alcohol abuse; articular birth defects; history of inflammatory arthropathy; history of spinal trauma or surgery; evidence of fracture, spondylolysis, spondylolisthesis, scoliosis or any other spinal condition other than osteoarthritis or osteoporosis.

All radiographs were inspected both to determine whether they depicted any evidence of spinal disease, as described in the exclusion criteria and for the presence of osteoarthritis. The assessment was conducted by two of the authors

independently and on two separate occasions. The examiners were blinded to patient's identity and to the results of any other tests. Interobserver and intraobserver agreement was excellent, reaching 99 and 98%, respectively.

After the application of exclusion criteria, from 524 patients that were examined, only 145 were initially considered as potentially suitable. The main reasons for exclusion were use of drugs that affect BMD ($n = 73$), vertebral compression fracture ($n = 68$), history of metabolic ($n = 42$) or endocrine disorders ($n = 53$), spinal birth defects (hemivertebra, sacralization or lumbarization, Scheuermann kyphosis etc.) ($n = 39$), spondylolysis ($n = 18$), scoliosis ($n = 11$), spondylolisthesis ($n = 10$), other ($n = 65$). A further 33 patients were excluded due to poor quality of their spinal radiographs. The final sample consists of 112 postmenopausal women, aged 42–76 years old (mean 57.3 years).

Measured characteristics

The patients' age, height and weight were recorded and their BMI calculated at the time of their visit to the hospital.

In order to determine physical activity status, all the patients were asked a standardized set of questions regarding their occupational and recreational activities and their physical activity level (PAL) was classified as sedentary, active or vigorous [29, 30]. Only two patients were classified as vigorous, and for the sake of simplicity they were grouped in the active group.

As an added and less subjective measure of physical activity, each individual's basal metabolic rate (BMR) was also calculated. BMR reflects a person's long-term physical activity [12, 34]. The calculations were performed using the Schofield equation (BMR_{SCH}) as well as the Harris–Benedict equation (BMR_{H-B}). The Schofield equation is the most widely used, as established from bibliographic citations, in addition to being recommended by the World Health Organization (WHO) [29, 30]. On the other hand, in a study by Taaffe et al. [36] the Harris–Benedict equation was shown to be the best among other published equations in predicting BMR as compared to indirect calorimetry in postmenopausal women.

Lumbar curvature measurements

Lumbar lateral radiographs were digitized and measurements were made using Cobb's method with the assistance of a computer program. The use of computers for lumbar lordosis measurements has been shown to be equivalent, if not superior, to the manual method [13, 28, 31]. Cobb's method has the best reproducibility and repeatability in lumbar curvature measurements [13]. 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, the angle between the bottom of L_5 to the top of S_1 (lumbosacral angle) was also measured.

Subject classification

Following data collection, the sample was divided into four groups: patients with OP, patients with OA, patients with OP and OA and controls. Osteoporosis was diagnosed if the patient's bone density level was more than 2.5 standard deviations or more below the young adult reference mean (T score) according to WHO criteria [43]. Osteoarthritis was defined as the presence of radiographically detectable lesions according to Kellgren and Lawrence [2]. At least two lesions needed to be present in order to establish the diagnosis [35]. Small osteophytes found only in the intervertebral joint space (disk space) were not considered to be evidence of primary OA (grade = 1 doubtful). The OP group comprises of 34 subjects, all of which had a T score < -2.5 SD in at least one site and no evidence of spinal OA on X-ray. The OA group comprises of 29 subjects, all of which had T score > -2.5 SD and some evidence of spinal OA. The OP and OA group included 20 subjects that had both a T score < -2.5 SD in at least one site and evidence of spinal OA. Finally the control group comprises of 29 subjects that had T score > -2.5 SD and no evidence of spinal OA.

Informed consent was provided from every subject to participate in this study. The protocol was approved by the Ethics Committee of the Faculty of Medicine, University of Crete.

Statistical analysis

The comparison of variables among the four groups was performed using the one factor ANOVA model with no repeated measurements. For pairwise multiple comparisons, Bonferroni's test was used. The categorical comparison of PAL between the four groups was performed using χ^2 test. 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

Age was significantly higher in the OP and in the OP, OA group compared to controls. It was also higher in the OP, OA group compared to the OA group. Even though there were differences in age when comparing the OA group with the OP group and controls, these did not attain statistical significance. Significant differences were found in subject's weight between groups. Specifically, patients in the OP group were lighter than controls and patients in the OP, OA

group were lighter than those in the OA group as well as controls. In contrast, the four groups were matched for BMI.

Comparison of PAL among the four groups did not reveal statistically significant differences. However, when BMR was compared between the groups, significant differences were found. Using the Harris–Benedict equation, the control group showed a higher BMR_{H-B} than the OP and the OP, OA groups. The OA group also had a higher BMR_{H-B} compared to the OP, OA group. Using the Schofield equation, BMR_{Sch} was again higher in the control group than in the OP, OA group. Similarly, it was higher in the OA group than in the OP, OA group.

None of the measured angles showed any significant difference between the groups. Our results show that on average, the four groups have similar lordosis and lumbosacral angles.

The means, standard deviations, and significance of comparisons of all measured characteristics for the four groups are summarized in Table 2.

Discussion

The findings of this study are in agreement with previously established correlations between anthropometric characteristics and the presence of osteoporosis or osteoarthritis. However, no significant differences were found in the degree

of lumbar lordosis and the lumbosacral angle between patients with osteoporosis, patients with lumbar spine osteoarthritis, patients with both diseases and healthy individuals. Consequently, although the presumptions that generated the tested hypothesis are valid, the results do not support it. This could be because of a number of reasons. It was thought that the degree of lordosis would express the combined effect of the common risk factors. Such an easily measured characteristic could have been helpful as a prognostic tool. However, it appears that the magnitude of effect of these risk factors on disease occurrence is different than that on spinal configuration. Another reason for which the hypothesis was invalidated could be that the other, not common factors that are involved have a significant influence on disease development and a negligible or no influence on lordosis. Lastly, it could be argued that the degrees of severity of both osteoporosis and osteoarthritis were not taken into account. It might be circumspectly assumed that if there should be a significant difference in spinal alignment, it could have been detected in the relatively severe cases of both diseases. However, BMD measurements are very inconclusive in advance stages of both osteoporosis and osteoarthritis. Osteoporotic spine fractures will appear as false negative due to the local high density, and osteoarthritic bone will always appear as dense, but actually may be very osteopenic in the parts not close to the joint.

Table 2 Means, standard deviations and overall significance of all measured characteristics

	OP (<i>n</i> = 34)	OA (<i>n</i> = 29)	OP + OA (<i>n</i> = 20)	Control (<i>n</i> = 29)	Sig.
Age (years)	59.1 (5.8) ^a	56.1 (6.6)	62.3 (6.3) ^{b,c}	53.1 (6.2)	<i>p</i> < 0.0005
Height (m)	154.5 (6.8)	157.3(6.5)	153.5(5.0)	155.7 (4.8)	<i>p</i> = 0.127
Weight (kg)	67.5 (10.0) ^d	72.3(12.2)	63.6 (8.7) ^{e,f}	74.7 (9.8)	<i>p</i> = 0.001
BMI (kg/m)	28.3 (3.9)	29.5 (5.5)	27.9 (3.1)	30.9 (4.4)	<i>p</i> = 0.246
PAL	1.7 (0.4)	1.6 (0.6)	1.6 (0.6)	1.6 (0.5)	<i>p</i> = 0.694
BMR_{H-B} (kcal/day)	1,288.6 (109.8) ^g	1,354.9 (111.0)	1,236.2 (100.3) ^{h,i}	1,385.3 (100.4)	<i>p</i> < 0.0005
BMR_{Sch} (kcal/day)	1,406 (83.4)	1,448.5 (101.1)	1,374.3 (72.4) ^j	1,465.9 (82.0)	<i>p</i> = 0.001
L ₁ –L ₅ (deg)	40.7 (11.5)	38.0 (15.1)	41.8(13.2)	38.6 (11.6)	<i>p</i> = 0.686
L ₁ –S ₁ (deg)	54.1 (12.5)	52.3 (12.9)	52.3(12.5)	51.8 (14.2)	<i>p</i> = 0.903
L ₅ –S ₁ (deg)	15.2 (7.1)	15.4 (5.4)	13.3 (6.1)	14.3 (4.8)	<i>p</i> = 0.605

Values outside parentheses are means; numbers in parentheses are standard deviations. PAL designations 1 = sedentary, 2 = active. BMR_{H-B} is BMR calculated with the Harris–Benedict equation, BMR_{Sch} is BMR calculated with the Schofield equation

^a denotes pairwise comparisons between *p* = 0.001 versus control

^b denotes pairwise comparisons between *p* = 0.005 versus OA

^c denotes pairwise comparisons between *p* < 0.0005 versus control

^d denotes pairwise comparisons between *p* = 0.045 versus control

^e denotes pairwise comparisons between *p* = 0.023 versus OA

^f denotes pairwise comparisons between *p* = 0.002 versus control

^g denotes pairwise comparisons between *p* = 0.003 versus control

^h denotes pairwise comparisons between *p* = 0.001 versus OA

ⁱ denotes pairwise comparisons between *p* < 0.0005 versus control

^j denotes pairwise comparisons between *p* = 0.023 versus OA

The relationship between lordosis and osteoporosis had not been adequately examined previously. Cortet et al. [4] compared lordosis in women with and without vertebral compression fractures. A curviscope was used to measure lordosis, and in the same paper it is stated that no correlation was found between measurements obtained by this instrument and those obtained from radiographs by the Cobb method. Using curviscope measurements, no difference in lumbar angle was found between the two groups of patients. In a subsequent study [5], curviscope measurements were not correlated with BMD in 20 women with vertebral compression fractures. Sinaki et al. [33] also found no correlation between lumbar angles and BMD in a sample of postmenopausal women. However, lordosis was defined as “the angle of intersection between the inferior border of the interference vertebra and the superior border of the sacrum”. Additionally, no discrimination was made between subjects with osteoporosis and controls.

The studies that examine the correlation of lordosis with spinal osteoarthritis have yielded contradictory results. Lin et al. [18] measured lordosis in a sample of 149 symptom-free Chinese adults, 45 of which had some evidence of osteoarthritis of their lumbar spine. They report no differences in lordosis between those with and without degenerative changes; however, the radiographs were taken in a lateral recumbent position with the hips and knees flexed, which has been shown to affect measurements [26]. Similarly, Lebkowski et al. [17] did not find diminished lordosis in patients with lumbar degenerative disk disease. On the other hand, Farhni and Trueman discovered smaller lordotic angles and lower incidence of degenerative changes in a cadaver sample of Indian men, compared with Caucasians [9]. Conversely, Jackson et al. [15] report smaller lordosis and lumbosacral angles in patients with lumbar degenerative disk disease compared to controls. A number of studies have been conducted where radiographic evidence of lumbar osteoarthritis was present and lordosis was measured, but no attempt was made to investigate any relationship between the two [14, 37, 39].

A limitation of this study is that involves only Caucasian, postmenopausal women. Any conclusions should be confined to this particular group of people alone. Another limitation is that a cross-sectional rather than a prospective design was chosen. Any future research on this subject should also focus on the progression of disease of particular patients and the alteration of their spinal curves over time. This would require the implementation of a prospective design in further studies. A longitudinal study would also help ascertain whether osteoporotic micro fractures lead to osteoarthritic changes; and vice versa: whether advanced arthritic changes lead to osteopenic changes. This in effect is implied by the finding of age being higher in the OP, OA group than in the OA group, which suggests that a number of

patients with spinal osteoarthritis will also develop osteoporosis at a later age. This finding contradicts the proposition that osteoarthritis might exert a protective effect on the progression of osteoporosis [40].

In conclusion, in the present cross-sectional study, no association was found between the degree of lumbar lordosis and the presence of osteoporosis, osteoarthritis, both diseases and absence thereof. Even though patients with these diseases have some different characteristics, lumbar lordosis does not appear to be one of them.

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