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Relationship between radiographic features and bone mineral density in elderly men

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Lumbar disc degeneration is characterised radiologically by the presence of osteophytes, endplate sclerosis, and disc space narrowing. Our study was designed to assess anterior lumbar osteophytes, disc space narrowing, end plate sclerosis, and bone mineral density (BMD) in the lumbar vertebrae and femoral neck of elderly men. A total of 1000 men, aged between 71 and 90 years, were invited to participate in the study. BMD was assessed at the spine and femoral neck using dual energy X-ray absorptiometry (DXA). We examined the relationship with the degree of lumbar spinal and femoral neck deformity by using the Z-score. Lateral and anterioposterior spinal radiographs were evaluated for features of lumbar disc degeneration. The observers consisted of a consultant physical therapist, a radiologist, and anatomists who together studied the series of radiographs. Anterior lumbar osteophytes (grade 0–3), end-plate sclerosis, and disc space narrowing (grade 0–2) were evaluated. The Pearson correlation test was used to determine the association between radiographic features, the lumbar mineral density (LBMD), and femoral neck mineral density (FNBMD). In all, 90.6% of lumbar vertebral levels showed evidence of anterior osteophytes, 87.5% showed evidence of end plate sclerosis, and 68.2% of disc space narrowing. Additionally, there was a strong negative correlation in terms of age at the femoral neck, though not at the spine. On the other hand, there was a significant correlation between osteophyte grade and end plate sclerosis at the spine. In our study, the radiographic features of lumbar disc degeneration, anterior osteophytes, and end plate sclerosis were associated with an increase in BMD at the spine. (Folia Morphol 2010; 69, 3: 170–176)

Key words: osteophytes, lumbar vertebrae, disc degeneration, DXA, digital radiography

INTRODUCTION

Disk degeneration has been linked to mechanical loading. The importance of mechanical factors has been emphasised by experiments on cadaver spines with both a severe single event and relentless loading [1, 2, 11, 27, 45]. Failure of disks is more common in areas where the heaviest mechanical stresses are present such as the lower lumbar region. It has been suggested that mechanical factors produce endplate damage, the antecedent to disk degeneration [3]. The disk is metabolically active, and the metabolism is dependent on diffusion of

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fluid either from the marrow of the vertebral bodies across the subchondral bone and cartilaginous endplate or through the annulus fibrosus from the surrounding blood vessels [13]. The importance of normal blood flow to the homeostatic nutritional process in the intervertebral disk complex has been suggested as an explaination for the association of atherosclerosis and aortic calcification with increased disk degeneration and subjective low back pain [17]. However, Nachemson [31] stated that in no more than 1 in 2000 patients do the radiographs of the spine constitute essential evidence for the diagnosis, prognosis, or treatment of low back pain. It has been reported in the literature that low back pain [24], sedentary life [9], and insufficient sportive activity are important factors for the development of low back pain. In addition, some authors indicate that low back pain has a familial component [4, 44], and in some studies it has been shown to be influenced by specific genetic risk factors such as COL9A1 [34, 38], aggrecan [18], vitamin D receptor [16, 19, 34, 47], and matrix metalloprotease-3 [34]. However, radiographic abnormalities such as intervertebral disc space narrowing, spinal osteophytes, Schmorl's nodes, transitional vertebrae, and accentuated lumbar lordosis have been commonly cited as significant findings in patients with low-back pain [6, 10, 20, 22, 46].

The term *degeneration* includes any or all of the following: real or apparent desiccation, fibrosis, narrowing of the disk space, diffuse bulging of the annulus beyond the disk space, extensive fissuring and mucinous degeneration of the annulus, defects and sclerosis of the endplates, and osteophytes at the vertebral apophyses. The lumbar region, which is usually used for bone mineral density measurements (L1–L4), is the most reproducible. Lumbar disc degeneration is characterised radiologically by the presence of disc space narrowing, osteophytes, and end plate sclerosis. Although osteophytes at the lumbar spine have been associated with an increase in bone mass at the spine, this may in part be the result of technical factors — osteophytes cannot be distinguished from vertebral bone mineral using bone mineral density area measurements [5, 8, 12, 15, 23, 26, 29, 30, 33, 40, 43, 48, 50]. Anterior and lateral marginal vertebral body osteophytes have been found in 100% of skeletons of individuals over 40 years of age, and therefore are the consequence of normal aging, whereas posterior osteophytes have been found in only a minority of skeletons of individuals over 80 years of age, and therefore are not inevitable consequences of aging [32]. Recent studies have shown that the bone mineral density (BMD) of lumbar vertebrae in postmenopausal women correlates with gene polymorphisms, and that some of the latter were associated with spinal osteophytosis and/or disc degeneration [28, 47, 49]. Furthermore, Sambrook et al. [44] recently concluded in a study of twins that genetic factors could explain 74% of cases with disc degeneration which was identified by magnetic resonance imaging. On the other hand, non-genetic factors such as body mass index also affect the skeletal features of degenerative changes [44].

The aim of our study was to evaluate and compare with radiographic features of lumbar disc degeneration in vivo by a graded semiquantitative score, age and bone mineral density in older men.

MATERIAL AND METHODS

Subjects

One thousand male patients who were admitted to Özel Veni Vidi Hospital between January 2009 and March 2010 were recruited for participation of vertebral osteoporosis. The subjects mean age was 77.04 ± ± 5.10. Height [m] and weight [kg] were assessed in all subjects. All individuals gave written informed consent to take part in the study, which also received the approval of the local ethics committee.

One thousand lumbar radiographs were available for review. Each vertebral level from L1/2 to L5–S1 was assessed by a physical therapist, a radiologist, and anatomists who together studied for the presence and grades of anterior lumbar osteophytes, end-plate sclerosis, and disc space narrowing. The intraobserver reproducibility had been assessed by the five observers who re-evaluated 50 films within 7 days of the first reading. The k score (average mean for five observers) was 0.79 for osteophytes, 0.73 for sclerosis, and 0.80 for disc space narrowing, indicating good reproducibility for all features.

Radiological evaluation

The subjects were given a physical activity questionnaire and were administered anterioposterior-lateral spinal radiographs and dual energy X-ray absorptiometry (LUNAR DPX 4.8a version, USA) at the spine and femoral neck. The observers consisted of a consultant physical therapist, a radiologist, and anatomists who together studied the series of radiographs. Evaluation of radiographic features of lumbar disc degeneration was performed by five independent observers blinded to the respective dual energy X-ray

Table 1. Correlations between bone mineral density, individual radiographic features, and age

		Age	LBMD	FNBMD	Osteophytes	Disc space narrowing	End plate sclerosis
Age	Pearson correlation	1	0.010	–0.64*	0.66*	0.91**	0.61*
	Sig. (2-tailed)		0.757	0.044	0.036	0.172	0.028
	N	1000	1000	1000	1000	1000	1000
LBMD	Pearson correlation	0.010	1	0.030	0.95**	0.051	0.91**
	Sig. (2-tailed)	0.757		0.337	0.003	0.109	0.002
	N	1000	1000	1000	1000	1000	1000
FNBMD	Pearson correlation	–0.64*	0.030	1	0.033	0.82**	0.028
	Sig. (2-tailed)	0.044	0.337		0.303	0.009	0.039
	N	1000	1000	1000	1000	1000	1000
Osteophytes	Pearson correlation	0.66*	0.95**	0.033	1	0.84**	0.81**
	Sig. (2-tailed)	0.036	0.003	0.303		0.008	0.287
	N	1000	1000	1000	1000	1000	1000
Disc space narrowing	Pearson correlation	0.91**	0.051	0.82**	0.84**	1	0.85**
	Sig. (2-tailed)	0.172	0.109	0.009	0.008		0.168
	N	1000	1000	1000	1000	1000	1000
End plate sclerosis	Pearson correlation	0.61*	0.91**	0.028	0.81**	0.85**	1
	Sig. (2-tailed)	0.028	0.002	0.039	0.287	0.168	
	N	1000	1000	1000	1000	1000	1000

*Correlation is significant at the 0.05 level (2-tailed); **correlation is significant at the 0.01 level (2-tailed); LBMD (lumbar mineral density) — Z-score of spine; FNBMD (femoral neck bone mineral density) — Z-score of femoral neck

absorptiometry (DXA) measurement results. DXA values were from Özel Veni Vidi Hospital as a routine patient protocol. Lumbar spine radiographs were taken according to a standard protocol with the film centred at L2. Radiographs were taken on the same day that the BMD was measured. Each vertebral level from L1–2 to L5–S1 was assessed for the presence and severity of anterior osteophytes (grade 0 — no osteophytes; grade I — small osteophytes; grade 2 — large osteophytes without bridge formation; grade 3 — large osteophytes with bridge formation), end plate sclerosis, and disc space narrowing using a semi-quantitative score (grade 0 — none — grade 1, mild; grade 2 — moderate).

Statistical analysis

The relation between BMD and radiographic features, together with age, was assessed by the Pearson correlation test. All analyses were performed with the SPSS statistical package in the Department of Biostatistics.

RESULTS

Subjects

In all, 1000 men (mean age 77.4 ± 5.10 years; mean height 1.63 ± 0.68 m; mean weight 62.04 ± ± 2.79 kg) were included in the analysis. Z-score average was –2.88 and –4.11 at the spine and femoral neck, respectively. In the lumbar region, anterior osteophytes, endplate sclerosis, and disc space narrowing were statistically significant correlated with DXA results by Pearson correlation test (Table 1). Moreover, the findings in question (transitional vertebrae, the positions of the fourth and fifth lumbar and lumbosacral vertebral bodies relative to the iliac crest, Schmorl's nodes, disc space wedging, lumbar lordosis, and non-structural scoliosis) were equally distributed, independent of back or lower limb symptoms.

Correlations among radiographic features

There was a significant relationship among the radiographic features, by Pearson correlation test. As the grades of anterior lumbar osteophytes increased, the grades of end plate sclerosis (r = 0.81) and disc space narrowing (r = 0.84) also increased. In addition, as the grade of disc space narrowing increased, only the grade of the end plate sclerosis increased also. We evaluated the number of anterior lumbar osteophytes on X-ray films. Additionally, 5200 pairs of anterior osteophytes were found across the intervertebral disc space at L1–L2, L2–L3, L3–L4, L4–L5, and L5–S1. An anterior lumbar vertebral osteophyte should be 2 mm or more in length according to the clas-

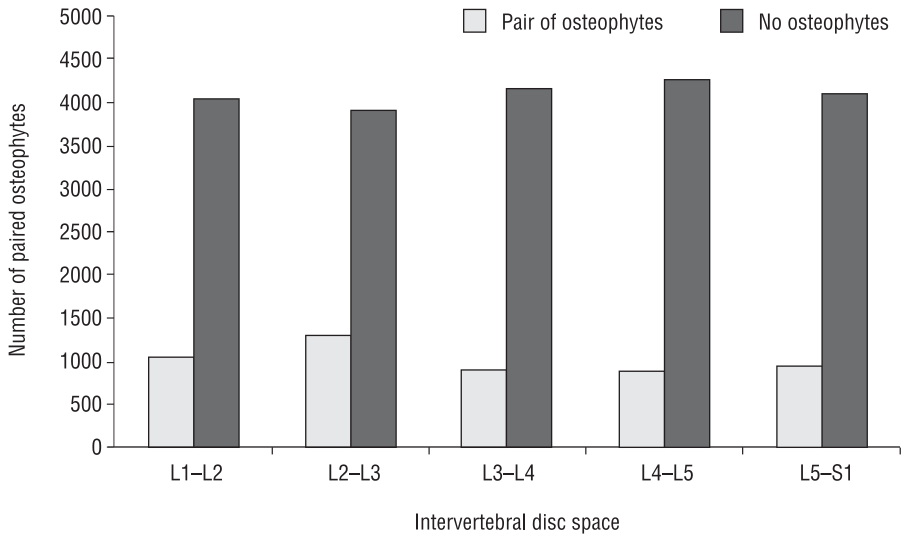

Figure 1. Number of anterior lumbar osteophytes by vertebral level.

sification of Macnab [25]. According to lumbar spine radiographs, 1098, 1272, 914, 893, and 1023 pairs of anterior osteophytes were found across the intervertebral disc space at L1–L2, L2–L3, L3–L4, L4–L5, and L5–S1, respectively (Fig. 1). The results of this study showed that pairs of osteophytes frequently formed in the upper lumbar vertebrae (L1–L2 and L2–L3). In all, 9.4%, 31%, 37.3%, and 22.3% of lumbar vertebrae had evidence of anterior osteophytes in grades 0–3, respectively (Table 2). In the entire level of L1–S1 there was 31.8% (none), 56.5% (mild), and 11.7% (moderate) of disc space narrowing (Table 2) and 12.5% (none), 40.4% (mild), and 47.1% (moderate) of end plate sclerosis in grades 0–2, respectively (Table 2).

Correlation between age and radiographic features

There was a statistically significant relationship among age, the grades of anterior osteophytes, end plate sclerosis and disc space narrowing. We confirmed that age positively correlated with the grade of radiographic features. As the age increased numerically, the grade of anterior osteophytes ($r = 0.66$) and end plate sclerosis ($r = 0.61$) also increased (Table 1). On the other hand, there seemed to be a statistical positive correlation between age and the grade of disc space narrowing ($r = 0.91$) (Table 1). This meant that the disc space decreased as the age increased.

Table 2. The numbers of grades by radiographic features

	Number (%)
Anterior lumbar osteophytes	
Grade 0	94 (9.4)
Grade 1	310 (31.0)
Grade 2	373 (37.3)
Grade 3	223 (22.3)
End plate sclerosis	
Grade 0 (none)	125 (12.5)
Grade 1 (mild)	414 (40.4)
Grade 2 (moderate)	471 (47.1)
Disc space narrowing	
Grade 0 (none)	318 (31.8)
Grade 1 (mild)	565 (56.5)
Grade 2 (moderate)	117 (11.7)

Correlation between age and FNBMD and LBMD

There was a negative correlation between age and femoral neck bone mineral density (FNBMD). As the age increased numerically, the Z-score ($r = -0.64$) decreased at the spine (Table 1). We considered that anterior lumbar osteophytes cannot be distinguished from vertebral bone mineral using BMD area measurements.

Correlation between LBMD and radiographic features

According to DXA results, there was no significant relationship between lumbar bone mineral density (LBMD) and the grade of disc space narrowing (r = 0.051) (Table 1). Conversely, there was a significant relationship between LBMD, the grade of anterior lumbar osteophytes, and end plate sclerosis. As the Z-score increased at the spine, the grade of anterior osteophytes (r = 0.95) and end plate sclerosis (r = 0.91) also increased (Table 1). This showed that there was a parallel relationship between LBMD, the grade of anterior osteophytes, and end plate sclerosis.

DISCUSSION

Our studies have demonstrated that findings from standing lateral and anterioposterior radiographs are associated with BMD in the lumbar vertebral bodies and femoral neck of elderly men. We evaluated the relationship between age, the grade of radiographic features (anterior lumbar osteophytes, end plate sclerosis, and disc space narrowing), and Z-score at the spine and femoral neck.

Many authors also evaluated the lumbar disc degeneration with BMD and radiographic features [14, 21, 23, 26, 35, 41, 42]. Masud et al. [26] assessed BMD at the spine and femoral neck. At the spine, they graded lateral spine radiographs independently of the severity of osteophytosis by the method of Orwoll et al. [36]. They were reported that the mean lumbar spine bone density measurements for age with osteophytosis reported significantly higher than in the group with no osteophytosis. The most severe osteophytosis group had an adjusted mean lumbar spine bone density 32.1% higher. Furthermore, they also determined the same result at the femoral neck in terms of osteophytes. The results of our study show that pairs of osteophytes frequently form at the L1–L2 and L2–L3 levels (Fig. 1). Additionally, large osteophytes without bridge formation were seen higher than other osteophyte formations (Table 2). Oishi et al. [35] reported that increases in osteophyte formation and BMD in the lumbar vertebrae were influenced by body weight and body mass index, which inversely correlated with BMD. At the spine, we observed that the grade of anterior lumbar osteophytes and end plate sclerosis increased in parallel with Z-score values. Pye et al. [41] stated that after age adjustment, BMD increased with grade for all radiographic features of disc degeneration in both men and women at the lumbar spine. Additionally, they reported that after age adjustment, BMD increased with osteophyte and end plate sclerosis grade though not with disc space narrowing. Similarly, we also detected that the grades of anterior lumbar osteophytes and end plate sclerosis correlated with Z-score at the lumbar spine. On the other hand, the grades of disc space narrowing only correlated with Z-score at the femoral neck. Accordingly, Liu et al. [23] reported that osteophytes were the most common feature, with men having a higher prevalence than women, and lumbar spine having more disease than hip. They observed that lumbar spine osteophytes affected 75% of men and 61.1% of women, and hip osteophytes affected 31.7% of men and 27.4% of women. Furthermore, their results related to disc space narrowing were compatible with ours. They stated that disk space narrowing showed no association with lumbar spine BMD in men or women [23]. Most studies looking at the relationship between disc degeneration and BMD at the spine and hip have been undertaken in women [12, 15, 26, 29, 43] with few data in men [14, 15, 23].

Torgerson and Dotter [46] identified a marginally significant association between low back pain and disc-space narrowing between the fourth and fifth lumbar vertebrae as assessed by pyelography. Conversely, in the study of O'Neill et al. [37] of over 680 women aged 50 years and older, recruited from primary care-based registers in 5 UK centres, the prevalence of mild to severe lumbar osteophyte was 84%, and no correlation was observed between low back pain and osteophyte formation.

As the disks undergo age-related degenerative changes, osteophytic outgrowths develop from the margins of the vertebral bodies. In general, the more advanced the changes in the disk, the larger or more extensive the development of osteophytes. Progressive reduction in the disk thickness is usually associated with the formation of increasingly large osteophytes. Osteophytes of the vertebral bodies occur earlier and grow to a larger size in the anterolateral regions. Osteophytes of substantial size may also involve the anterior or posterior region. The cause of osteophyte formation remains largely speculative. It has been suggested that disk degeneration leads to tilting of the vertebral bodies and the anterior squeesing of the disk, which then bulges forward and elevates the adjoining periosteum to stimulate new bone formation [7]. However, microscopic studies do not provide convincing evidence for his concept. Instead, these studies indicate that osteophytes form, at least initially, by endochondral ossification. Torsion has been found to cause annular tears, but those tears are circumferential and do not cause the nucleus to herniate. The study of anterior lumbar vertebral osteophytes by O'Neill et al. [37] demonstrated that X-ray examination of the lumbar spine of subjects screened for osteoporosis exhibited an increased frequency of anterior lumbar vertebral osteophytes with aging. Furthermore, Watanabe et al. [51] reported that there was a positive correlation between the size of osteophytes and the age of patients in whom the size of lumbar vertebral osteophytes was measured during autopsy. These studies indicated that osteophytes were caused by aging changes. On the other hand, anterior lumbar vertebral osteophytes have been reported to occur most frequently at L3–L4, and more frequently in men [37, 39] and obese patients [35] or those who undergo heavy phy-sical activity [37] than in women or other patients. In our study, anterior lumbar vertebral osteophytes were seen mainly at L2–L3 level, and the most visible types of osteophyte were large osteophytes without bridge formation (grade 2). In addition, we determined that age was statistically related to the grades of anterior lumbar osteophytes, end plate sclerosis, and disc space narrowing. In connection with these radiographic features seen in older men, disc space narrowing decreased in parallel with age.

The results of this study showed that increasing in BMD correlated with the presence of anterior lumbar osteophytes and end plate sclerosis at the spine. Even if osteophytes and end-plate sclerosis are independent and separately related to narrowing of the disc, the grades of these features would increase in parallel. In addition, all radiographic features significantly correlated with age. Additionally, we determined that pairs of osteophytes frequently formed in the direction of the adjacent disc in upper lumbar vertebrae (L1–L2 and L2–L3). These findings could offer additional information for the assessment of lumbar disc degeneration in older men.

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