EXTENDED REPORT

Radiographic features of lumbar disc degeneration and bone mineral density in men and women

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Objectives: To determine the association between individual radiographic features of lumbar disc degeneration and bone mineral density (BMD) at the spine and hip.

Methods: Subjects were recruited from a population register for a screening survey of vertebral osteoporosis. BMD was assessed at the spine and hip using dual energy x ray absorptiometry. Lateral spinal radiographs were evaluated for features of lumbar disc degeneration. Each vertebral level from L1/2 to L4/5 was assessed for the presence and severity of osteophytes, end plate sclerosis, and disc space narrowing. Linear regression was used to determine the association between each of these features and BMD at the spine and hip, with adjustments for age, body mass index, and levels of physical activity. Analyses were done separately in men and women.

Results: 250 women and 256 men (mean age around 65 years) were studied. At the lumbar spine, after age adjustment there was an increase in BMD with increasing grade for all radiographic features of disc degeneration in both men and women. At the femoral neck, after age adjustment there was an increase in BMD with increasing osteophyte and end plate sclerosis grade though not disc space narrowing. Adjusting for body mass index and physical activity did not influence the strength of the associations.

Conclusions: Radiographic features of lumbar disc degeneration are associated with an increase in BMD at the spine. Osteophytes and end plate sclerosis, but not disc space narrowing, are associated with an increase in BMD at the hip.

There is evidence for an inverse association between the occurrence of osteoarthritis and bone mass—individuals with osteoarthritis having a higher bone mass than those without.^{1–3} Most studies have focused on the association between bone mass and osteoarthritis at either the hip, knee, or hand. Less is known about the association between bone mass and degenerative disease in the spine. 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 (BMD) area measurements.^{4–16} Several studies have examined the association between osteophytes and bone mass at distant sites including the hip and most, though not all, suggest that they are also linked to an increased bone mass.^{4 6 7 10 13–16} Relatively little, however, is known about the association between the other radiographic features of disc degeneration, including end plate sclerosis and disc space narrowing, and BMD at distant sites.

In the few published studies there are conflicting findings about the association between bone mass at the hip and disc space narrowing,^{10 13 15 16} and negative findings relating to the association with end plate sclerosis.^{13 16} Further data are required to explore these relations.

In a study of women with hip osteoarthritis, the association with bone mass at several skeletal sites was stronger for those with hip osteophytes than for joint space narrowing. It was suggested this was consistent with the hypothesis that individuals with higher bone mass may have a predisposition to develop osteoarthritis, particularly trophic variants characterised by osteophytes.⁹ Based on the observation, we hypothesised that any association between lumbar disc degeneration and non-spine BMD would be stronger for lumbar osteophytes than for disc space narrowing. The aim of

our study was to determine the association between individual radiographic features of lumbar disc degeneration and BMD at the spine and hip. We also examined whether confounding by body mass index or levels of physical activity might explain any observed associations.

METHODS

The subjects included in this analysis were recruited for participation in a screening survey of vertebral osteoporosis in Aberdeen, UK.¹⁷ The sampling frame was a community health index based on primary care registrants.¹⁸ Stratified random sampling was used, with the aim of recruiting equal numbers of men and women in each of six 5 year age bands: 50 to 54, 55 to 59, 60 to 64, 65 to 69, 70 to 74, and 75 years and over. Subjects were invited by letter to attend for an interviewer administered lifestyle questionnaire, lateral spinal radiographs, and dual energy x ray absorptiometry (Norland XR26, Cooper Medical, Milwaukee, Wisconsin, USA) at the spine and femoral neck. Height (m) and weight (kg) were assessed in all subjects. Body mass index (BMI) was calculated as weight divided by height squared (kg/m²). All individuals gave written informed consent for their participation in the study, which also received the approval of the local ethics committee.

The questionnaire included questions concerning the level of physical activity undertaken at work or home during three periods of adult life: 15 to 25 years, 25 to 50 years, and 50 years and over (response set: light (1) / moderate (2) / heavy (3) / very heavy (4)), and time spent walking or on a bicycle out of doors each day (response set: none / some, but less than ½ hour / ½ to 1 hour / more than 1 hour).¹⁹ We defined a total physical activity score as the sum of the values across all three age periods with increasing values representing greater levels of physical activity (range 3 to 12). For current

Abbreviations: BMD, bone mineral density; BMI, body mass index

Table 1 Subject characteristics

Variable	Men (n = 250)	Women (n = 256)
Age (years)	65.4 (9.0)	65.1 (8.9)
Lumbar spine BMD (g/cm ²)	1.06 (0.21)	0.87 (0.19)*
Femoral neck BMD (g/cm ²)	0.83 (0.13)	0.72 (0.13)*
BMI (kg/m ²)	26.4 (3.5)	25.9 (4.6)
Total activity score (/12)	7.2 (2.0)	6.0 (1.9)*
Walking >1 hour per day	64.8%	44.9%*

Values are mean (SD) unless stated otherwise.

*p<0.05.

BMD, bone mineral density; BMI, body mass index.

activity we categorised individuals as those who walked or cycled for at least one hour a day and those who walked or cycled less than this.

Radiographs

Lumbar spine radiographs were taken according to a standard protocol with the film centred at L2. The radiographs were subsequently evaluated by a single observer for the presence of the individual radiographic features of disc degeneration. Each vertebral level from L1/2 to L4/5 was assessed for the presence and severity of anterior osteophytes, end plate sclerosis, and vertebral narrowing, using a reference atlas and a semiquantitative score (grade 0, none; grade 1, mild; grade 2, moderate; grade 3, severe). In the atlas, images were chosen to illustrate the cut off points for changes rather than a "typical appearance" for each. Films

were evaluated over a two week interval and intraobserver reproducibility was assessed by the same observer who re-evaluated 60 films within one week of the first reading. The κ score, a measure of agreement, was 0.83 for osteophytes, 0.75 for sclerosis, and 0.82 for vertebral narrowing, indicating good reproducibility for all features. Using the atlas we have recently reported the descriptive epidemiology of the features.²⁰

Analysis

We defined, for each radiographic feature, two summary statistics: "MAX", which was the grade of the most severely affected vertebral level per subject (from L1/2 to L4/5) and which could range from 0 to 3, and "SUM", the sum of the four vertebral specific grades per subject which thus could range from 0 to 12. Linear regression was used to determine the association between each of the three radiographic features (using both MAX and SUM) and BMD (dependent variable) at the spine and femoral neck, separately in men and women. Adjustments were made for age and subsequently for BMI and physical activity levels. We examined MAX as a continuous variable to test for any trend of increasing bone mass with increasing grade of radiographic feature. We examined MAX as a categorical variable as well, to determine the mean BMD (and 95% confidence intervals (CI)) in g/cm² for each of the individual grades. We examined SUM as a continuous variable to test for any trend of increasing bone mass with increasing grade of feature with the results expressed as β coefficients and 95% confidence intervals. Statistical analysis was done using STATA.²¹

Table 2 Maximum grade (MAX) of individual radiographic features and bone mineral density at lumbar spine in men and women

		Lumbar spine BMD (g/cm ²) (mean (95% CI))		
	MAX†	n	Adjusted for age	Adjusted for age, BMI, and physical activity‡
Men				
Osteophyte	Grade 0	9	0.82 (0.69 to 0.95)	0.86 (0.72 to 1.00)
	Grade 1	89	0.99 (0.95 to 1.04)	1.02 (0.93 to 1.12)
	Grade 2	89	1.08 (1.04 to 1.12)	1.11 (1.01 to 1.20)
	Grade 3	62	1.16 (1.11 to 1.21)*	1.18 (1.08 to 1.28)*
Sclerosis	Grade 0	104	1.01 (0.97 to 1.05)	1.01 (0.92 to 1.10)
	Grade 1	104	1.06 (1.02 to 1.10)	1.07 (0.97 to 1.16)
	Grade 2	35	1.20 (1.13 to 1.27)	1.20 (1.10 to 1.31)
	Grade 3	6	1.21 (1.04 to 1.38)*	1.18 (1.00 to 1.37)*
Disc space narrowing	Grade 0	96	1.01 (0.97 to 1.05)	1.00 (0.91 to 1.10)
	Grade 1	86	1.03 (0.98 to 1.06)	1.01 (0.91 to 1.10)
	Grade 2	39	1.15 (1.09 to 1.22)	1.13 (1.03 to 1.24)
	Grade 3	28	1.20 (1.12 to 1.28)*	1.20 (1.09 to 1.31)*
Women				
Osteophyte	Grade 0	19	0.79 (0.71 to 0.87)	0.80 (0.70 to 0.90)
	Grade 1	148	0.85 (0.82 to 0.88)	0.86 (0.79 to 0.93)
	Grade 2	66	0.92 (0.88 to 0.96)	0.93 (0.85 to 1.01)
	Grade 3	23	0.97 (0.90 to 1.05)*	0.97 (0.87 to 1.07)*
Sclerosis	Grade 0	142	0.84 (0.81 to 0.87)	0.82 (0.76 to 0.89)
	Grade 1	83	0.88 (0.84 to 0.92)	0.86 (0.79 to 0.94)
	Grade 2	20	0.96 (0.89 to 1.04)	0.94 (0.85 to 1.04)
	Grade 3	11	1.12 (1.02 to 1.22)*	1.09 (0.98 to 1.21)*
Disc space narrowing	Grade 0	83	0.83 (0.79 to 0.87)	0.82 (0.75 to 0.89)
	Grade 1	111	0.86 (0.83 to 0.90)	0.85 (0.78 to 0.92)
	Grade 2	27	0.90 (0.84 to 0.97)	0.90 (0.81 to 1.00)
	Grade 3	35	1.00 (0.95 to 1.06)*	0.99 (0.91 to 1.07)*

*p<0.05.

†Defined as maximum grade per subject.

‡Total activity score (3–12) and current activity (see text).

BMD, bone mineral density; CI, confidence interval.

Table 3 Maximum grade (MAX) of individual radiographic features and bone mineral density at femoral neck in men and women

		Femoral neck BMD (g/cm ²) (mean (95% CI))		
	MAX†	n	Adjusted for age	Adjusted for age, BMI and physical activity‡
Men				
Osteophyte	Grade 0	9	0.73 (0.65 to 0.81)	0.72 (0.63 to 0.81)
	Grade 1	88	0.80 (0.77 to 0.83)	0.77 (0.71 to 0.83)
	Grade 2	88	0.85 (0.82 to 0.88)	0.82 (0.76 to 0.88)
	Grade 3	62	0.87 (0.84 to 0.91)*	0.84 (0.78 to 0.90)*
Sclerosis	Grade 0	102	0.81 (0.79 to 0.84)	0.77 (0.72 to 0.83)
	Grade 1	104	0.84 (0.81 to 0.86)	0.80 (0.74 to 0.86)
	Grade 2	35	0.88 (0.84 to 0.92)	0.84 (0.77 to 0.91)
	Grade 3	6	0.86 (0.76 to 0.97)*	0.81 (0.70 to 0.93)*
Disc space narrowing	Grade 0	95	0.84 (0.81 to 0.87)	0.80 (0.74 to 0.86)
	Grade 1	85	0.82 (0.79 to 0.84)	0.77 (0.71 to 0.83)
	Grade 2	39	0.85 (0.81 to 0.89)	0.80 (0.73 to 0.87)
	Grade 3	28	0.84 (0.79 to 0.89)	0.81 (0.73 to 0.88)
Women				
Osteophyte	Grade 0	19	0.68 (0.63 to 0.73)	0.70 (0.63 to 0.76)
	Grade 1	148	0.71 (0.69 to 0.73)	0.72 (0.67 to 0.76)
	Grade 2	66	0.75 (0.72 to 0.77)	0.76 (0.71 to 0.81)
	Grade 3	23	0.78 (0.73 to 0.83)*	0.78 (0.71 to 0.84)*
Sclerosis	Grade 0	142	0.71 (0.69 to 0.72)	0.71 (0.66 to 0.75)
	Grade 1	83	0.74 (0.71 to 0.76)	0.74 (0.69 to 0.79)
	Grade 2	20	0.74 (0.69 to 0.79)	0.75 (0.68 to 0.81)
	Grade 3	11	0.79 (0.72 to 0.86)*	0.79 (0.71 to 0.86)*
Disc space narrowing	Grade 0	83	0.73 (0.70 to 0.75)	0.73 (0.68 to 0.77)
	Grade 1	111	0.72 (0.70 to 0.75)	0.72 (0.67 to 0.76)
	Grade 2	27	0.69 (0.65 to 0.73)	0.70 (0.64 to 0.76)
	Grade 3	35	0.73 (0.70 to 0.78)	0.73 (0.68 to 0.78)

*p<0.05.

†Defined as maximum grade per subject.

‡Total activity score (3–12) and current activity (see text).
BMD, bone mineral density; CI, confidence interval.

RESULTS

Subject characteristics

There were 585 subjects (286 men and 299 women) with lumbar spinal radiographs, of whom 506 (86%) had BMD measurements at the spine or hip or both. The characteristics of the 250 men and 256 women who had any BMD measurements are shown in table 1. Mean age and BMI were similar in men and women. At both the spine and hip sites, BMD was significantly higher in men than in women. Compared with women, men had a higher total activity score, and a greater proportion reported walking or cycling for more than one hour per day. There was no significant difference in age, BMI, or physical activity levels among those with any BMD measurement (506) and those without (79) (data not shown).

Maximum grade of radiographic feature (MAX) and BMD

Lumbar spine

The association between the maximum grade of radiographic feature per subject (MAX) and BMD at the lumbar spine for each of the three features is shown in table 2. After adjusting for age, lumbar spine BMD increased with increasing grade for each of the three features, a trend that was significant (p<0.05) for all features in both men and women. For example, the mean age-adjusted lumbar spine BMD was 0.82 g/cm² (95% CI, 0.69 to 0.95) for men free of osteophytes. This rose to 1.16 g/cm² (1.11 to 1.21) for men with grade 3 osteophytes. The trend towards increasing BMD with increasing grade of feature persisted after further adjusting for BMI and physical activity levels. In a model including age

and all three radiographic features, the trend towards increasing BMD with increasing grade was significant for osteophytes and disc space narrowing in men and for sclerosis and disc space narrowing in women (data not shown).

Femoral neck

The association between MAX and BMD at the femoral neck for each of the radiographic features is shown in table 3. After adjusting for age, femoral neck BMD increased with increasing grade for both osteophytes and sclerosis, a trend that was statistically significant in both men and women (p<0.05). For example, the mean age adjusted femoral neck BMD was 0.73 g/cm² (95% CI, 0.65 to 0.81) for men without osteophytes and 0.87 g/cm² (0.84 to 0.91) for men with grade 3 osteophytes. In contrast, however, there was no association between femoral neck BMD and disc space narrowing in either men or women. Indeed the mean femoral neck BMD was similar in those with grade 0 and those with grade 3 disc space narrowing. Further adjustment for BMI and physical activity levels did not affect any of the results. In a model including age and all three radiographic features, the trend towards increasing BMD with increasing grade was significant for osteophytes only in men and women (data not shown).

Summary score for radiographic features (SUM) and BMD

The influence of the radiographic features on BMD at all measurement sites—as assessed using the total score (SUM) across all four intervertebral levels—is shown in table 4. The

Table 4 Total scores (SUM) of individual radiographic features and bone mineral density at the spine and femoral neck in men and women

	Spine: β coefficient (95% CI)		Femoral neck: β coefficient (95% CI)	
	Age adjusted	Adjusted for age, BMI, and activity [‡]	Age adjusted	Adjusted for age, BMI, and activity [‡]
Men				
Osteophyte [†]	0.03 (0.02 to 0.04)*	0.03 (0.02 to 0.04)*	0.02 (0.01 to 0.02)*	0.01 (0.01 to 0.02)*
Sclerosis [†]	0.04 (0.02 to 0.05)*	0.04 (0.03 to 0.05)*	0.01 (0.00 to 0.02)*	0.01 (0.00 to 0.02)*
Disc space narrowing [†]	0.03 (0.02 to 0.04)*	0.03 (0.02 to 0.04)*	0.00 (−0.01 to 0.01)	0.00 (−0.00 to 0.01)
Women				
Osteophyte [†]	0.03 (0.02 to 0.04)*	0.03 (0.02 to 0.04)*	0.01 (0.01 to 0.02)*	0.01 (0.01 to 0.02)*
Sclerosis [†]	0.03 (0.02 to 0.05)*	0.03 (0.02 to 0.05)*	0.01 (0.00 to 0.02)*	0.01 (0.00 to 0.02)*
Disc space narrowing [†]	0.02 (0.01 to 0.03)*	0.02 (0.01 to 0.03)*	0.00 (−0.01 to 0.01)	0.00 (−0.00 to 0.01)

* $p < 0.05$.[†]Defined as total score across all intervertebral levels.[‡]Total activity score (3–12) and current activity (see text).

BMD, bone mineral density; BMI, body mass index; CI, confidence interval.

results are presented as β coefficients. These may be interpreted as the absolute change in BMD (g/cm^2) per unit change in score. Thus, for example, after age adjustment in men BMD increased by a value of 0.03 g/cm^2 for each unit change in the total osteophyte score. Overall, the results are broadly similar to those observed for the MAX score. Thus spine BMD increased as SUM increased for all three radiographic features. Femoral neck BMD increased as SUM increased for osteophytes and sclerosis; however, there was no association with disc space narrowing. The associations were similar in men and women and remained unchanged after adjustment for BMI and levels of physical activity.

DISCUSSION

In this analysis we have shown that increasing grade of osteophyte and end plate sclerosis were associated with increasing BMD at the spine and hip. Increasing grade of disc space narrowing was associated with BMD at the spine though not at the hip. None of the observed associations could be explained by differences in BMI or levels of physical activity.

Our study was population based and used a standard protocol in taking the radiographs. There are, however, methodological issues to be considered in interpreting the results. The response rate for participation in the study was 61%.²² It is possible that those who declined to participate differed with respect to their bone mineral density and the occurrence of disc degeneration from those who did take part; however, this should not have influenced our main findings which were based on an internal comparison of those recruited to the study.

We used a semiquantitative score to classify the radiographic features of disc degeneration. As with any subjective evaluation, this is subject to errors of interpretation which may result in misclassification. However, the κ score, which is a measure of agreement, was good for all three features, indicating good reproducibility.²³ Furthermore the individual (SP) responsible for assessment of the radiographs was unaware of the BMD status, so any misclassification is likely to have been random and to have reduced the chance of finding significant associations.

In our study the questionnaire instrument concerning current and lifetime levels of physical activity was relatively crude. It is possible that the lack of effect of physical activity on the association between bone mass and the radiographic features of disc degeneration was because of failure of the questions to capture accurately the typical recreational,

leisure, and occupational activities of the subjects. Further studies incorporating more detailed information about the type, frequency, and intensity of physical activities undertaken both currently and in the past would be required to explore this further. Finally, our data were derived from a white population in north-east Scotland and may not be extrapolated to other groups.

Previous studies have examined the association between lumbar disc degeneration and BMD at the spine, though few studies have looked separately at all three component radiographic features. Among women our data are consistent with previous reports suggesting an association between osteophytes and bone mineral density at the lumbar spine.^{4–6–16} Few studies have examined the association with the other radiographic features of disc degeneration, though the data are consistent with our finding of an association with end plate sclerosis^{8–9–12–13–16} and also disc space narrowing.^{8–9–15–16} It has been suggested that the association between features of disc degeneration and BMD at the spine may be an artefact resulting from the presence of osteophytes which cannot be distinguished from vertebral bone mineral using BMD area measurements. Indeed the presence of disc disease has been suggested as an explanation for the lack of any age related loss of bone at the spine.^{10–24} Studies that have looked at the relation between disc degeneration and BMD using quantitative computed tomography and lateral dual energy x ray absorptiometry—which might be expected to be less affected by the presence of osteophytes—have produced somewhat discrepant results.^{8–11–15–25}

Among women, most^{4–6–7–10–15} though not all^{13–14–16} studies suggest a link between bone mass at the hip and the presence of spinal osteophytes. There are conflicting data about the association with disc space narrowing,^{10–13–15–16} and negative findings for sclerosis.^{13–16} Unlike the spine, the presence of osteophytes at the hip is less likely to result in an artefactual increase in bone mass as the area of measurement is distant from the site where osteophytes usually occur.

Most studies looking at the association between disc degeneration and BMD at the spine and hip have been undertaken in women, with few data in men.^{10–13–26} Our findings suggest similar associations in men and women. Furthermore there was evidence of a dose–response relation in both sexes, with increasing grade of radiographic feature being linked to increasing bone mass.

Our data support the hypothesis that degenerative disc disease is inversely linked with osteoporosis. An association between hip osteoarthritis and an increase in bone mass was

first suggested by Foss and Byers.¹ Since then many studies have reported an association between bone mass and osteoarthritis, particularly at the hip and knee.² The mechanism is unknown though several are possible, including confounding by environmental or constitutional factors, hormonal, metabolic, and genetic factors.²⁷⁻²⁸ Increased body mass index is associated with an increase in bone mass and in some studies an increased risk of degenerative spine disease. Similarly, physical activity levels are linked to an increase in bone mass and have also been linked to osteoarthritis. Our results remained unchanged after adjustment for these factors, suggesting that they do not play a major role in explaining the observed associations. We cannot, however, exclude an association with other lifestyle or constitutional factors that were not assessed here, neither can we exclude gene-environment interactions.

In our study there was an association between hip BMD and both lumbar osteophytes and sclerosis, though not disc space narrowing. These findings are consistent with the view that mechanisms underlying the occurrence of bone proliferative responses associated with disc degeneration and the maintenance of bone mass in the adult skeleton may be linked. The findings are broadly consistent with a study of hip osteoarthritis in which BMD at both appendicular and axial sites was associated with the presence and size of hip osteophytes, while isolated narrowing without osteophytes was not linked to higher bone density.⁹

Conclusion

Radiographic features of lumbar disc degeneration are associated with an increase in bone mineral density at the spine. Osteophytes and end plate sclerosis, though not disc space narrowing, are associated with an increase in bone mineral density at the hip. These associations could not be explained by differences in body mass index or physical activity levels.

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