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Computed tomography–evaluated features of spinal degeneration: prevalence, intercorrelation, and association with self-reported low back pain

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Abstract

BACKGROUND CONTEXT—Although the role of radiographic abnormalities in the etiology of nonspecific low back pain (LBP) is unclear, the frequent identification of these features on radiologic studies continues to influence medical decision making.

PURPOSE—The primary purposes of the study were to evaluate the prevalence of lumbar spine degeneration features, evaluated on computed tomography (CT), in a community-based sample and to evaluate the association between lumbar spine degeneration features. The secondary purpose was to evaluate the association between spinal degeneration features and LBP.

STUDY DESIGN—This is a cross-sectional community-based study that was an ancillary project to the Framingham Heart Study.

SAMPLE—A subset of 187 participants were chosen from the 3,529 participants enrolled in the Framingham Heart Study who underwent multidetector CT scan to assess aortic calcification.

OUTCOME MEASURES—Self-report measures: LBP in the preceding 12 months was evaluated using a Nordic self-report questionnaire. Physiologic measures: Dichotomous variables indicating the presence of intervertebral disc narrowing, facet joint osteoarthritis (OA), spondylolysis, spondylolisthesis, and spinal stenosis and the density (in Hounsfield units) of multifidus and erector spinae muscles were evaluated on CT.

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METHODS—We calculated the prevalence of spinal degeneration features and mean density of multifidus and erector spinae muscles in groups of individuals with and without LBP. Using the χ^2 test for dichotomous and *t* test for continuous variables, we estimated the differences in spinal degeneration parameters between the aforementioned groups. To evaluate the association of spinal degeneration features with age, the prevalence of degeneration features was calculated in four age groups (less than 40, 40–50, 50–60, and 60+ years). We used multiple logistic regression models to examine the association between spinal degeneration features (before and after adjustment for age, sex, and body mass index [BMI]) and LBP, and between all degeneration features and LBP.

RESULTS—In total, 104 men and 83 women, with a mean age (±standard deviation) of 52.6±10.8 years, participated in the study. There was a high prevalence of intervertebral disc narrowing (63.9%), facet joint OA (64.5%), and spondylolysis (11.5%) in the studied sample. When all spinal degeneration features as well as age, sex, and BMI were factored in stepwise fashion into a multiple logistic regression model, only spinal stenosis showed statistically significant association with LBP, odds ratio (OR) (95% confidence interval [CI]): 3.45 [1.12–10.68]. Significant association was found between facet joint OA and low density of multifidus (OR [95% CI]: 3.68 [1.36–9.97]) and erector spinae (OR [95% CI]: 2.80 [1.10–7.16]) muscles.

CONCLUSIONS—Degenerative features of the lumbar spine were extremely prevalent in this community-based sample. The only degenerative feature associated with self-reported LBP was spinal stenosis. Other degenerative features appear to be unassociated with LBP.

Keywords

Low back pain; Computed tomography; Spine; Degeneration

Introduction

Low back pain (LBP) is a pervasive problem that affects two-thirds of adults at some time in their lives [1]. Back pain and its sequelae place an enormous burden on society, healthcare systems, and the economies of developed countries [2]. Despite the high prevalence of LBP, little is known about the pathogenesis of this complaint. In clinical practice, some clinicians routinely request imaging to confirm their diagnosis and provide reassurance. Others limit the use to patients who require interventional treatment or who have signs of potentially serious diseases, for they argue that imaging could provide misleading information, generate unnecessary anxiety, and lead to inappropriate treatment [3,4]. The clinical literature includes multiple reports of the high prevalence of degenerative spinal changes in asymptomatic individuals and does not support a significant relationship between such changes and the development of LBP [5–7].

Although the role of radiographic abnormalities in the etiology of nonspecific LBP is unclear, the frequent identification of these features on radiologic studies continues to influence medical decision making with respect to additional evaluation and selection of treatment options. In primary care settings, the most common spine imaging tests for assessing LBP are plain radiography, computed tomography (CT), magnetic resonance imaging (MRI), and bone scanning. Low cost and ready availability make plain radiography the most common of these [8,9]. However, a systematic review of published observational studies found no strong evidence supporting the presence of a causal relationship between radiographic findings and nonspecific LBP [10]. Clinical studies have consistently failed to demonstrate a significant relationship between spinal degeneration and LBP based on data from plain radiographic testing. However, the poor quality of imaging studies has been cited as a potential reason that the relationship between degeneration and LBP could not be defined.

In contrast to radiography, CT optimizes delineation of bony architectural details that are particularly relevant to degenerative disease (Figure). These details include end plate irregularity and sclerosis, spinal stenosis, facet joint osteoarthritis (OA), spondylolysis, and spondylolisthesis. Abnormalities that can be demonstrated and categorized by CT include osteophyte formation; hypertrophy of articular processes; articular cartilage thinning; vacuum phenomenon in joints and discs; synovial and subchondral cysts; and calcification of the joint capsule, vertebral end plates, and ligaments [11–13]. A review of the clinical literature revealed no CT-based studies evaluating the prevalence of structural abnormalities in the spine and their relation to LBP in an unselected population-based cohort.

The aim of the present study was to evaluate the association between degenerative features of the lumbar spine evaluated on CT and self-reported LBP in a community-based sample. Furthermore, we also examined the relation between different lumbar spine degeneration features including intervertebral disc narrowing, facet joint OA, spondylolysis, spondylolisthesis, and spinal stenosis and the density of multifidus and erector spinae muscles.

Methods

Study design

This is a cross-sectional community-based study that was an ancillary project to the Framingham Heart Study.

Sample

This project was an ancillary project to the Framingham Heart Study. This study began in 1948 as a longitudinal population-based study of the causes of heart disease. Initially, 5,209 men and women living in Framingham, MA, were enrolled. In 1971, 5,124 offspring (and their spouses) of the original cohort were entered into the Offspring cohort. In 2002, 4,095 men and women who were children of the Offspring cohort were enrolled in the Third Generation cohort. A description of the Offspring and Third Generation cohorts has been previously reported [14,15]. Abdominal and chest multidetector CT scanning was performed on 3,529 participants of the Offspring and Third Generation cohorts aged 40 to 80 years to assess coronary and aortic calcification. The recruitment and conduct of CT scanning have been previously reported [16,17]. During the later part of the CT study, 191 participants were consecutively enrolled in this ancillary study to assess the association between radiographic features of the lumbosacral spine and LBP. Four individuals were not analyzed because of insufficient CT data.

Low back pain evaluation

Participants undergoing multidetector CT scan were asked to complete the modified Nordic Low Back Questionnaire [18]. The first question on this questionnaire was, “Have you had low back pain on most days of at least one month in the last 12 months?” Individuals, who answered “yes” or “no” for the above question, were categorized in the present study as having back pain (dichotomous index). In addition, participants were asked if they experienced pain in the buttocks or thighs, pain in a lower leg (below the knee), numbness or tingling in the leg or foot, or weakness in the leg or foot. Similar methods were widely used in studies of work-related LBP [19–21].

Imaging parameters

All eligible participants were imaged with an eight-slice multidetector CT (Lightspeed Ultra; GE, Milwaukee, WI, USA). Each subject underwent unenhanced abdominal CT that was performed using a sequential scan protocol with a slice collimation of 8×2.5 mm (120 KVp,

320/400 mA for 0.220 lbs body weight) during a single end-inspiratory breath hold (typical duration, 18 seconds). For the abdominal scan, 30 contiguous 2.5-mm-thick slices of the abdomen were acquired covering 150 mm above the level of S1.

Evaluation of spinal degeneration features

For CT reading, we used transverse plan images as well as sagittal and coronal reconstructions, where needed. A reading protocol for evaluation of spinal degeneration features was developed. Using this protocol, the intra-and inter-rater reliability were calculated for two readers. One investigator, blinded to patient identifiers, read all the CTs. All spinal degeneration features were evaluated between L2 and S1 spinal levels. To evaluate reader drift, we reassessed intra-rater reliability by inserting one original reliability scan for every 10 new scans. Before analyzing each new set of CT scans, five previously analyzed CTs were reevaluated to “recalibrate” the readings to a standard.

Intervertebral disc narrowing

Disc narrowing was estimated on a sagittal reconstruction image using the four-grade scale by Videman et al. [22]: 0—normal, disc height greater than the cephalad disc, except for the L5–S1 disc; 1—slight, disc height equal to the cephalad disc if it is normal; 2—moderate, disc height less than cephalad disc if it is normal; and 3—severe, end plates almost in contact. For this study, this scale was collapsed to two grades: 1—normal, included Grades 0 and 1; and 2—affected, included Grades 2 and 3. The subject with at least one affected level was considered as having intervertebral disc narrowing.

Facet joint OA

Four grades (0—normal, 1—mild, 2—moderate, and 3—severe degeneration) of facet joint OA were defined using criteria that were described in Kalichman et al. [23] and similar to those published by Pathria et al. [24] and Weishaupt et al. [25]. This semiquantitative score accounts for such changes as joint space narrowing, osteophytes, hypertrophy of the articular process, subarticular sclerosis, subchondral cysts, and vacuum phenomenon. Lumbar facet joints were graded on both sides at L2–L3, L3–L4, L4–L5, and L5–S1 levels. For this study, this index was dichotomized on the basis of the presence or absence of facet joint OA (Grade 2 or more) on any side at any level.

Spondylolysis and spondylolisthesis

The lumbar spine was reviewed for each case using bone windows. Spondylolysis and spondylolisthesis were defined as present or absent (dichotomous indices) for each subject.

Spinal stenosis

Bone and soft-tissue windows were used. For measurements of congenital spinal stenosis, the midsagittal diameter of the spinal canal was measured at the level of the middle of the vertebra using a CT bone window. Acquired spinal stenosis was measured as a midsagittal diameter of the spinal canal at the level of the intervertebral disc (the effective canal diameter was determined between the margin of the intervertebral disc anteriorly and the junction of bilateral ligamenta flava posteriorly) using a CT soft-tissue window. Spinal stenosis was defined as diameter less than 10 mm in accordance with previous studies [26–30]. A dichotomous index was obtained on the basis of the presence or absence of lumbar spinal stenosis of any type and at any level.

Evaluation of the density of paraspinal muscles

The density of multifidus and erector spinae muscles was measured in Hounsfield units on both the left and right sides at the level of the upper end plates of L3, L4, and L5 vertebrae.

Mean density was measured by a 6-mm circle in the center of muscle mass in the region of interest. A similar method was previously used in the study by Keller et al. [31] of paraspinal muscle density.

To avoid the problem of multiple comparisons and because there were no significant differences between right and left sides and between spinal levels, we performed principal component analyses for each muscle separately, using the original density measurements. The first principal components derived from these analyses were dichotomized according to the following rule: lowest 33.3% of the distribution = 1, other = 0. Resulting dichotomous indices were used in the further analyses.

Body mass index

Body mass index (BMI) was computed as the ratio of the body mass in kilograms divided by the height in square meters.

Statistical analysis

We first calculated the prevalence of various spinal degeneration features and mean density of multifidus and erector spinae muscles in groups of individuals with and without LBP and in the total sample. Using the χ^2 test for dichotomous variables and *t* test for continuous variables, we estimated the differences in spinal degeneration parameters between the aforementioned groups. Second, the population was divided into four age strata: less than 40, 40 to 49, 50 to 59, and 60+ years. The prevalence of each degeneration feature was calculated in each stratum. To evaluate the association of spinal degeneration features with age, we calculated the p for trend using Cochran-Armitage trend test. Then, we evaluated the association between each spinal degeneration feature and LBP before and after adjustment for age, sex, and BMI using logistic regression analyses. We also evaluated the association between spinal degeneration features and LBP using multiple logistic regression analyses (normal and stepwise models), where LBP was the dependent variable and all studied degeneration features as well as age, sex, and BMI were independent predictors.

Results

Results of reliability tests (kappa statistics) were as follows: The intraobserver reliability for disc narrowing varied at different spinal levels between 0.84 and 0.90. The inter-observer reliability for disc narrowing ranged from 0.78 to 0.88. The intraobserver reliability for grading different facet joint OA indices varied between 0.64 and 0.91 and the interobserver reliability ranged from 0.59 to 0.94. The intraobserver reliability for identification of spondylolysis was 1.00 and the interobserver reliability was 0.98. For spondylolisthesis, the intraobserver reliability varied at different levels between 0.95 and 1.00 and the interobserver reliability ranged from 0.75 to 0.98. For spinal stenosis, the intraobserver reliability varied at different spinal levels between 0.95 and 0.98 for congenital stenosis and between 0.92 and 0.98 for acquired stenosis. The interobserver reliability ranged from 0.80 to 0.92 and from 0.86 to 0.96, respectively, for congenital and acquired stenosis. The intraobserver reliability for multifidus and erector spinae at different levels varied between 0.94 and 0.99. The inter-observer reliability ranged from 0.70 to 0.97. This range of kappa statistics represents good to excellent reproducibility.

In the studied sample, 37 (19.4%) subjects reported experiencing LBP on most days of at least 1 month in the last 12 months. Among them, 28 also complained of distal symptoms.

Table 1 shows the basic demographic characteristics and prevalence of spinal degeneration features in the study sample as well as the results of comparison between groups of individuals with and without LBP. Of note was a high prevalence of intervertebral disc

narrowing (63.9%) and facet joint OA (64.5%) in the study sample. Significant differences between groups of individuals with and without LBP were found in the prevalence of spinal stenosis (p=.041). Difference at p=.097 level was found in the mean density of erector spinae.

Prevalence of spinal degeneration features in different age groups as well as estimation of linear trend probability are presented in Table 2. Prevalence of disc narrowing, facet joint OA, degenerative spondylolisthesis, and low densities of multifidus and erector spinae showed a significant association (p<.0001 for each degeneration feature) with increasing age.

In the simple logistic regression analyses between unadjusted variables, LBP showed a significant association with density of multifidus (odds ratio [95% confidence interval]: 2.13 [1.03–4.40]) and close to significant association with spinal stenosis (2.68 [0.91–7.91]) and density of erector spinae (1.85 [0.89–3.84]). Facet joint OA was significantly associated with other spinal degenerative features, such as disc narrowing (2.04 [1.10–3.80]), spondylolysis (3.80 [1.08–13.40]), degenerative spondylolisthesis (16.67 [2.20–126.30]), and low density of multifidus (7.23 [3.05–17.10]) and erector spinae (6.01 [2.64–13.70]). Disc narrowing also showed significant association with degenerative spondylolisthesis (7.59 [1.73–33.30]) and low density of multifidus (2.19 [1.11–4.33]) and erector spinae (2.81 [1.39–5.71]) and close to significant association with spinal stenosis (3.56 [0.77–16.40)]. Degenerative spondylolisthesis showed significant association with density of multifidus (5.48 [2.21–13.60]) and erector spinae (6.84 [2.67–17.50]).

Using multiple logistic regression analyses, we evaluated the associations between different spinal degeneration features and between those features and LBP while adjusting for age, sex, and BMI (Table 3). Only spinal stenosis showed close to significant association with LBP (2.87 [0.93–8.87]). Facet joint OA showed significant association with low density of multifidus (3.68 [1.36–9.97]) and erector spinae (2.80 [1.10–7.16]) and close to significant association with spondylolysis (3.60 [0.93–13.90]) and degenerative spondylolisthesis (7.22 [0.90–57.90]). Degenerative spondylolisthesis showed close to significant association with disc narrowing (4.61 [0.99–21.4]) and low density of multifidus (2.68 [0.92–7.77]).

When all CT-evaluated spinal degeneration features as well as age, sex, and BMI were factored in stepwise fashion into a multiple logistic regression model, only spinal stenosis showed a significant association with self-reported LBP (odds ratio [95% confidence interval]: 3.45 [1.12–10.68]). The results of the Hosmer test of the goodness of fitness for this regression model were χ^2=9.97, p=.27.

Discussion

This is the first cross-sectional study to describe simultaneously the prevalence of comprehensive CT-evaluated spinal degeneration features in a community-based population. The results show a high prevalence of intervertebral disc narrowing (63.9%) and facet joint OA (64.5%) in the studied sample. The reported prevalence of disc space narrowing is slightly higher than that previously reported in MRI studies [32–35]. In those studies, the reported prevalence of disc space narrowing for asymptomatic subjects varied between 37% [33] and 56% [34]. In samples selected regardless of LBP status, the prevalence of disc space narrowing has varied between 13% to 53% [32] and 5% to 36% [35]. The prevalence of facet joint OA in the general population was recently reported for the first time by our group [23].

The 11.5% prevalence of spondylolysis identified in this study is nearly double the 6% rate that has been generally believed to be true based on previous epidemiologic studies [36,37].

All previous studies of spondylolysis prevalence, including the oft-cited Scandinavian population study by Virta et al. [37], have reported data from large screening programs based solely on plain radiographs. A likely explanation for the significantly higher rate identified in the present study is the use of CT. The use of advanced imaging of any kind for the study of prevalence of facet joint OA, spondylolysis, and disc space narrowing is unique to this study, as is the utilization of an unselected community-based study population.

In the vast majority of cases of LBP, a clear diagnosis cannot be made. Features associated with spinal degeneration such as intervertebral disc degeneration, facet joint OA, spondylolysis, spondylolisthesis, spinal stenosis, and degenerative changes in paraspinal muscles are often identified on advanced imaging studies but are also commonly seen in asymptomatic individuals [5,6,38–45]. In the present community-based study, we have found no association between most CT-evaluated spinal degeneration features, except spinal stenosis, and the occurrence of LBP. Based on these results, the use of CT as a single diagnostic modality for LBP cannot be supported. We found no relation between facet joint OA, disc narrowing, spondylolysis, and spondylolisthesis and LBP. This suggests that these features are not significantly associated with LBP in the general population and suggests caution in attributing the occurrence of LBP to these findings.

Another modern imaging modality that is widely used in the evaluation of spinal pathology and LBP is MRI. It has the ability to detect changes in the water content of biological tissues and can produce highly detailed images. Magnetic resonance imaging is particularly good for depicting internal disc morphology. Abnormalities, such as a dehydrated or degenerated disc, appearing as a dark or low signal on T2-weighted MRI, can be frequently seen on MRI of the lumbar spine of patients with chronic LBP. However, they are also often seen in asymptomatic individuals [43]. The use of MRI is generally accepted where tumor, infection, insufficiency fracture, or disc protrusion is suspected, but its use as a screening tool for chronic LBP is debatable, given its cost and complexity [46,47].

Accurate determination of the origin of LBP can potentially provide a more rational approach to patient management. However, the most available imaging techniques can currently only provide a partial solution [47]. Additional studies are needed to improve our understanding of the association between morphological changes and LBP. First, additional large-scale population-based follow-up studies with detailed description of LBP symptoms and use of state-of-the-art imaging technologies are needed. Second, more attention must be paid to soft-tissue changes. A growing body of studies has demonstrated an association between changes in paraspinal muscles and LBP [48–51]. And finally, all imaging-evaluated morphological changes to explain LBP must be considered as a part of complex bi-opsychosocial model [52] in line with environmental, occupational, psychological, and other factors.

We also evaluated the association between the respective CT-evaluated degenerative features of the lumbar spine. After adjustment for age, sex, and BMI, facet joint OA showed significant association with low density of multifidus and erector spinae, and degenerative spondylolisthesis showed close to significant association with low density of multifidus. The comparable association, between knee OA and degeneration in adjoined quadriceps muscle, was widely described [53,54]. Circumferentially, our results are in accord with the study of O'Sullivan et al. [55] that found that specific training of paraspinal muscles significantly reduces pain and disability in individuals with spondylolysis and spondylolisthesis. It would be interesting to explore if the strengthening exercise for paraspinal muscles will prevent the development of facet joint OA and degenerative spondylolisthesis.

There are several limitations of the present study. First, because this is a cross-sectional sample, conclusions regarding increasing prevalence of spinal degeneration features with increasing age are inferred by examining individuals in different age groups rather than following a sample population longitudinally. Second, although the cross-sectional design of this study allows evaluating associations between degeneration features, it cannot be used for evaluation of causal relationships. Third, for age-specific prevalence of spinal degeneration features, we did not do multiple comparison tests. Each feature is a distinct structure, and as such it can be argued that we are testing unique associations. Even so, we recognize that multiple testing is a potential source of positive associations that occur by chance. Fourth, the LBP index used in this study, although commonly used in work-related LBP studies, is not sufficiently detailed to provide data regarding pain radiation, pain prolongation, and severity. In particular, the absence of detailed information regarding back pain severity, frequency, and resultant functional limitation greatly limits the potential for the study to inform clinical decision making. However, the authors believe that the study message is to reinforce the concept that degenerative features are commonly observed with advanced imaging technology, in this case CT, and that caution should be used before concluding that such features are pathologic. Additional important limitations in the study design include the lack of physician confirmation of patient-reported symptoms and a relatively small sample size.

Conclusions

This ancillary project to the Framingham Heart Study is the first community-based study of the prevalence of CT-evaluated lumbar spinal degeneration features in an unselected population. It is confirmed that degenerative features of the lumbar spine are extremely prevalent in the general community. A statistically significant association was found between facet joint OA and the density of multifidus and erector spinae. The only degenerative feature associated with self-reported LBP was spinal stenosis. Other degenerative features appear to be unassociated with pain and may be features of normal aging.

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EVIDENCE & METHODS

Context

The population prevalence of degenerative findings on advanced imaging can provide important information regarding specificity of some findings.

Contribution

This study, using computer tomography in a small cohort of the Framingham Heart Study, confirms previously reported information in cadaveric, plain radiographic, and MRI studies. Gross degenerative findings appear to be very common and, in the absence of spinal stenosis (<10 mm), their correlation to clinical back pain syndromes are poor.

Implication

Clearly most degenerative findings are not associated with serious back pain illness. This study provides some estimate of baseline pre-test probabilities in a community-based sample with a broad spectrum of symptoms. Pre-test probabilities calculated for a specific clinical population (e.g. those *with* low back pain, *with* radiculopathy, *with* neurogenic claudication) may further clarify diagnostic-test utility of specific findings in specific patient presentation patterns.

— The Editors

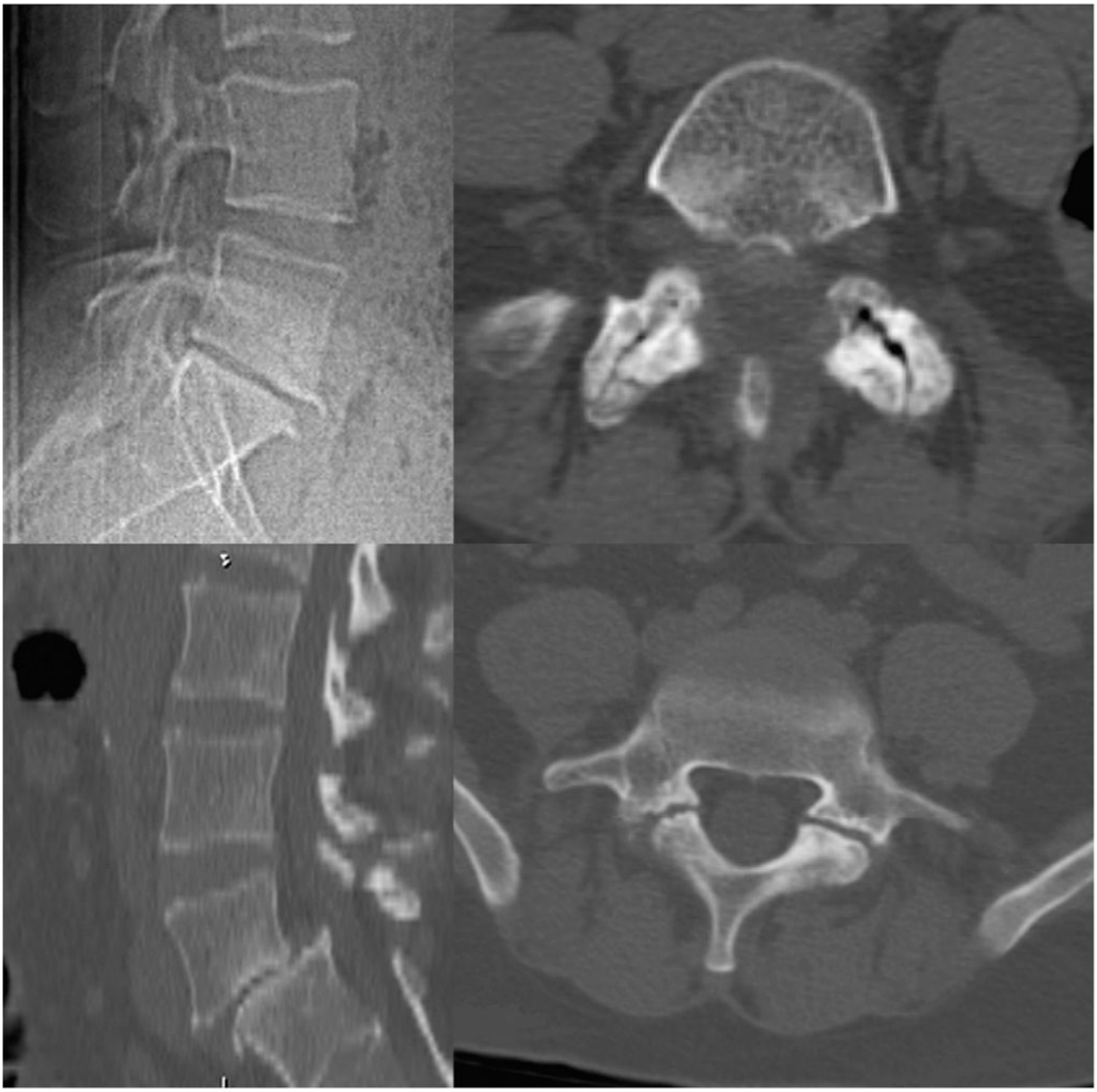

Figure.
Examples of evaluated computed tomography images. (Top left) L5–S1 intervertebral disc narrowing; (Bottom left) spondylolisthesis L5–S1 is shown on sagittal reformatted image; (Top right) facet joint osteoarthritis; and (Bottom right) bilateral spondylolysis of L5 is shown on an axial view image.

Table 1

Prevalence of spinal degeneration features in individuals with and without LBP

Degeneration features and covariates	Group with LBP	Group without LBP	Total	Comparison between groups (p Value)
N	150	37	187	
Sex (males), n (%)	18 (48.7)	86 (57.3)	104 (55.6)	.3410
Disc narrowing, n (%)	27 (73.0)	90 (61.6)	117 (63.9)	.1999
Facet joints OA, n (%)	24 (66.7)	94 (64.0)	118 (64.5)	.7598
Spondylolysis, n (%)	5 (13.9)	16 (10.9)	21 (11.5)	.6122
Isthmic spondylolisthesis, n (%)	4 (10.8)	11 (7.5)	15 (8.2)	.5085
Degenerative spondylolisthesis, n (%)	6 (15.8)	19 (12.8)	25 (13.6)	.6015
Spinal stenosis, n (%)	6 (16.2)	9 (6.0)	15 (8.0)	**.0405**
Age (y), mean ± SD	54.4±9.3	52.2±11.1	52.6±10.8	.2643
BMI (kg/m^2), mean ± SD	28.7±5.5	27.6±4.9	27.8±5.0	.2279
Mean density of multifidus (HU), mean ± SD	58.1±16.6	62.3±9.3	61.4±11.2	.1462
Mean density of erector spinae (HU), mean ± SD	51.9±12.7	55.7±9.3	55.0±10.1	*.0965*

BMI, body mass index; HU, Hounsfield units; LBP, low back pain; OA, osteoarthritis; SD, standard deviation.

Results of χ^2 test for dichotomous variables and of *t* test for continuous variables. Statistically significant differences at p≤.05 level are in bold; associations significant at p≤.10 level are italicized.

Table 2

Age-specific prevalence of spinal degeneration features

Degeneration features	<40 y	40–49 y	50–59 y	60+ y	p Value trend
Disc narrowing, n (%)	6 (25.0)	26 (55.3)	45 (70.3)	30 (83.3)	<**.000**1
Facet joints OA, n (%)	6 (25.0)	21 (44.7)	49 (76.6)	42 (87.5)	<**.0001**
Spondylolysis, n (%)	2 (8.3)	4 (8.5)	6 (9.4)	9 (18.8)	.1348
Isthmic spondylolisthesis, n (%)	2 (8.3)	4 (8.5)	4 (6.2)	5 (10.4)	.8208
Degenerative spondylolisthesis, n (%)	0 (0)	1 (2.1)	7 (10.8)	17 (35.4)	<**.0001**
Spinal stenosis, n (%)	2 (8.0)	1 (2.1)	4 (6.1)	8 (16.3)	*.0635*
Density of multifidus, n (%)	1 (4.2)	7 (14.9)	21 (32.8)	33 (68.8)	<**.0001**
Density of erector spinae, n (%)	1 (4.2)	7 (14.9)	24 (37.5)	30 (62.5)	<**.0001**

OA, osteoarthritis.

Associations significant at p≤.05 level are in bold; associations significant at p≤.10 level are italicized.

Table 3

Association between predictors (and low back pain), adjusting for age, sex, and body mass index

Degeneration features	Facet joints OA	Spondylolysis	Isthmic spondylolisthesis	Degenerative spondylolisthesis	Spinal stenosis	Density of multifidus	Density of erector spinae	LBP
Disc narrowing	1.13 (0.54–2.36)	0.83 (0.29–2.38)	0.53 (0.17–1.66)	*4.61 (0.99–21.4)*	2.97 (0.58–15.1)	1.25 (0.53–2.94)	1.77 (0.77–4.09)	1.44 (0.62–3.34)
Facet joints OA		*3.60 (0.93–13.9)*	2.79 *(0.69–11.3)*	*7.22 (0.9–57.9)*	0.55 (0.14–2.16)	**3.68 (1.36–9.97)**	**2.80 (1.10–7.16)**	0.81 (0.34–1.93)
Spondylolysis			*	0.67 (0.13–3.40)	2.18 (0.52–9.18)	0.93 (0.27–3.25)	1.62 (0.52–5.06)	1.53 (0.50–4.68)
Isthmic spondylolisthesis				0.49 (0.06–4.25)	2.20 (0.42–11.6)	2.39 (0.62–9.17)	2.07 (0.56–7.63)	1.68 (0.49–5.74)
Degenerative spondylolisthesis					2.12 (0.51–8.75)	1.64 (0.52–5.20)	*2.68 (0.92–7.77)*	0.92 (0.30–2.80)
Spinal stenosis						2.15 (0.54–8.63)	1.73 (0.46–6.55)	*2.87 (0.93–8.87)*
Density of multifidus							**8.92 (3.71–21.5)**	1.89 (0.74–4.86)
Density of erector spinae								1.50 (0.62–3.64)

LBP, low back pain; OA, osteoarthritis.

Data are given as odds ratio (95% confidence interval). Significant associations are highlighted bold; marginally significant are italicized.

*To avoid the undefined result (it was no patients with isthmic spondylolisthesis but without spondylolysis), this estimate was not computed.