Cross-Sectional Study of the Correlation between a Novel Lumbar Spine Radiography Scoring System and Disability due to Low Back Pain

Baek Peter[1], Moran Sheila[1], Tracey Olivia[1], Kirschenbaum Ira[1] and Simela Ashley[2]*

[1]*Orthopaedic Surgeon, University Hospitals, Richmond Medical Center, Cleveland, OH, USA*

[2]*Orthopaedic Surgeon, BronxCare Health System, Bronx, NY, USA*

*Corresponding Author: Simela Ashley, Orthopaedic Surgeon, BronxCare Health System, Bronx, NY, USA.

Abstract

Objective: Low back pain is often an indication for lumbar spine radiography. Radiographic observation of spondylolisthesis, anterior osteophytes, and disc space narrowing can be used as indicators of lumbar disc degeneration (LDD), however, a standardized scoring system of lumbar spine radiography does not exist. This study aims to create a standardized scoring system of lumbar spine radiography for utilization by orthopedic surgeons and relate this score to the patient's level of disability due to low back pain. The level of disability due to low back pain is measured using the Oswestry Disability Index (ODI) and variables such as patient age, BMI, and sex are also studied.

Methods: A cross-sectional study was conducted on 49 patients with low back pain at the BronxCare Health System Department of Orthopaedics outpatient clinic from 2015 to 2018 in the Bronx, United States. A radiographic scoring system was developed to quantify the severity of LDD through a 4 item numeric rating scale; presence of spondylolisthesis (0 = absent, 1 = present), presence of anterior osteophytes (0 = absent, 1 = present), presence of multi-level spondylolisthesis/anterior osteophytes (0 = absent, 1 = present), and presence of severe disc degeneration (0 = absent, 1 = bone-on-bone contact due to disc degeneration). The minimum score is 0 and the maximum score is 4. The increase in numeric rating indicates greater LDD. The severity of disability was assessed using the Oswestry Disability Index, a 10 item survey quantifying the level of disability due to low back pain. The minimum score of the questionnaire is 0 and maximum score is 50. Correlation tests were conducted to relate all features of the lumbar spine radiography to the patients' level of disability, age, body mass index (BMI), and sex.

Results: Mean age was 53.1 years old ± 9.9 years and 24 (48.9%) were females while 25 (51%) were males. Mean BMI was 29.6 ± 5.3, with 20 (40.8%) obese patients. Mean severity of disability was 30.12 ± 9.32 with 1 mildly disabled, 7 moderately disabled, 21 severely disabled, 15 crippled, and 8 bed bound, as defined by the Oswestry Disability Index. 19 patients (38.9%) had spondylolisthesis, 28 (57.1%) had anterior osteophytes, 23 (46.9%) had adjacent degeneration in the lumbar spine, and 19 (38.8%) had complete disc space collapse. Mean radiography score was 1.82 ± 1.09. Advancing age was correlated with radiography score. Spondylolisthesis was correlated with severity of disability. Advancing age may be correlated with severity of disability.

Conclusion: Within this newly developed lumbar spine radiography scoring system, only spondylolisthesis was found to correlate with the severity of disability due to low back pain.

Keywords: *Lumbar Spine Radiography; Low Back Pain*

Background

Low back pain is the leading contributor to disability worldwide [1]. This chronic condition afflicts more than 31 million American annually. Low back pain is a debilitating condition that impacts one's quality of life as it pervades physiologically, but also psychologically [2]. Chronic low back pain is often associated with mechanical injuries, while the onset of the aging spine is pathologically associated

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with Lumbar Disc Degeneration (LDD) [3]. LDD is defined as the degeneration of the fibrocartilage pads that serve as lumbar discs are distributed between the vertebrae to equalize the biomechanical force placed on the spine. The most common method of diagnosis of LDD is lumbar spine radiographic imaging. However, x-rays often do not provide a definitive diagnosis. Given the vast number of etiologies of low back pain, there exists no standardized protocol to assess lumbar spine radiographic images. Moreover, the correlation between the radiographic features of LDD and the disability associated with low back pain has not been adequately studied [4].

The two variables, disability due to low back pain and the radiographic features of LDD, can be assessed by patient-reported and provider-assessment forms of measurement. Disability caused by low back pain is measured by the Oswestry Disability Index (ODI). The ODI serves as the gold standard of reporting patients' permanent functional disability due to low back pain. This questionnaire encompasses multiple health domains that impact quality of life such as pain intensity, personal care, movement, social life, employment, and traveling [5]. While the Oswestry Disability Index has been evaluated for reliability and validity [6], no current method exists for correlating x-ray features of LDD to the level of patient disability. Furthermore, the evidence of association between LDD and disability has received mixed reviews. The primary radiographic features of LDD include spondylolisthesis, anterior osteophytes, multiple level disc degeneration, and disc space collapse [7]. It is important to note that while both disc space narrowing and osteophytes are signs of increasing LDD, only disc space narrowing is associated with disability [8]. In addition, the disc space narrowing has been found to correlate with spondylolisthesis and disability [3].

The correlation between LDD and disability can also be influenced by factors such as age, gender and BMI. Older age and an overweight BMI have been identified as increased risk factors for lumbar disc degeneration [9,10]. Consistent data on the effects of gender on LDD and disability were not identified.

This study was conducted at the BronxCare Health System in the South Bronx, New York. This urban setting is recognized as the most diverse community in the United States. The South Bronx is the poorest district in the nation with 28.6% of residents living below the poverty line [11]. The population of the South Bronx also has high rates of overweight and obese residents, with 41% of the population classified as overweight and 25% classified as obese [12].

Aim of the Study

This study aims to create a standardized scoring system of lumbar spine radiography and to relate this score to the patient's level of disability due to low back pain, as measured by the Oswestry Disability Index. This study also aims to assess the role of sex, age and BMI on LDD and disability.

Methods

A cross-sectional study was conducted on 49 patients with low back pain who attended the BronxCare Health System Department of Orthopedics outpatient clinic in the Bronx, New York between 2015 and 2018. The cohort included both male and female patients aged 30 to 71 with low back pain. Age, sex, and BMI were collected before clinical evaluation. A total of 13 patients were removed from the initial sample due to the lack of available preoperative imaging or lack of BMI data.

Disability was measured using the Oswestry Disability Index (ODI), a low back pain questionnaire evaluating the impact of disability due to low back pain (Figure 1). Patients reporting low back pain (n = 49) at the BronxCare Health System Department of Orthopaedics outpatient clinics were individually screened with the questionnaire during the preoperative clinical phase. Those that declared Spanish as their preferred language were screened with the Spanish version of the survey. The questionnaire encompasses multiple health domains that impact quality of life such as pain intensity, personal care, movement, social life, employment, and traveling [5]. Each of the ten sections lists six potential options which range in level of disability. Each section was scored from 0 to 5 with higher values indicating greater disability. The total sum of responses was calculated and presented as both discrete values and percentages. The minimum score of the questionnaire is 0 and maximum score is 50. An increase in the total score indicates an increase in disability due to low back pain.
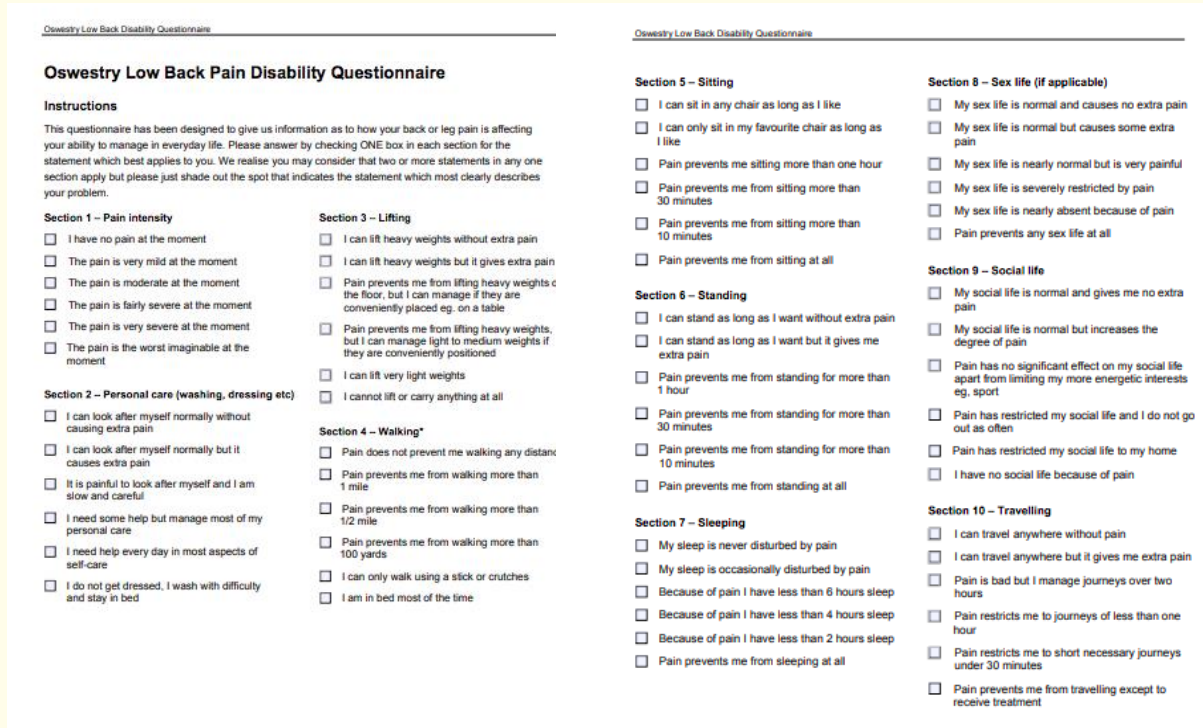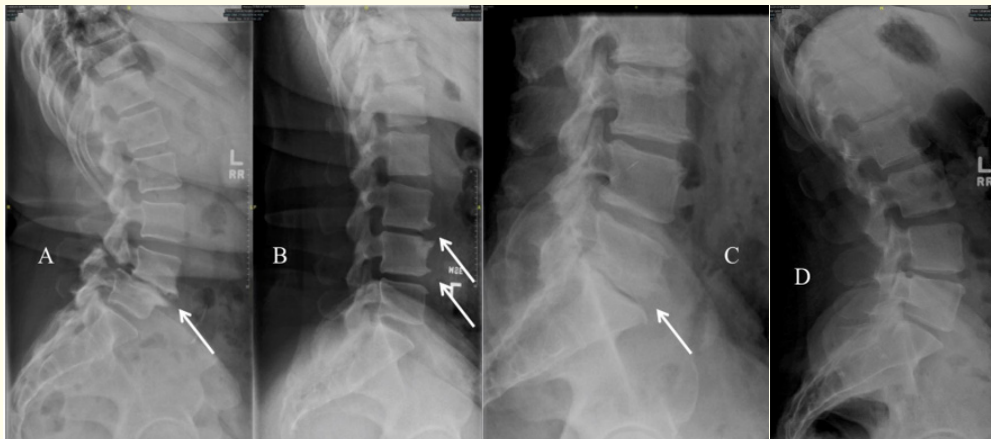
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Figure 1: *Copy of oswestry disability index questionnaire [5].*

For the radiographic features of LDD, static or flexion/extension frontal and lateral lumbar x-rays were collected for all patients in the preoperative clinical phase. The intervertebral disc space (L1/L2 to L5/S1) in the collected x-rays were evaluated for presence of spondylolisthesis, anterior osteophyte formation, and bone-on-bone vertebral contact due to total disc space narrowing/collapse. Spondylolisthesis is defined as the displacement of an injured vertebra relative to other surrounding healthy vertebra. Anterior osteophytes are classified as bony projections growing anteriorly on the superior and inferior surfaces of the vertebra. Severe disc space collapse is defined as total loss of disc space, resulting in contact between the inferior and superior surfaces of two adjacent vertebra. A novel radiographic scoring system was developed to quantify these results. The radiographic features of LDD were identified through visual analysis of each x-ray (Figure 2). Each of these categories was graded as: 0 = absence or 1 = presence. A fourth category was added for adjacent level degeneration, defined as the presence of anterior osteophytes and/or spondylolisthesis on an adjacent vertebra. This was graded as: 0 = one (or no) vertebra affected or 1 = two or more adjacent vertebrae affected by degeneration. Overall LDD was calculated by summing these four categories, resulting in a grade range of 0 to 4, with higher scores indicating increasing disc degeneration. End plate sclerosis was not assessed due to lack of consistency among evaluators [3].

Interobserver reliability of radiography scoring system was tested with two additional orthopedic surgeons trained in radiographic evaluation who graded the same 49 lumbar x-rays using this scoring criteria. Both surgeons were blinded to the researchers' interpretation of data.

Multivariable analysis was performed using linear regression models to evaluate the correlation between age, BMI, severity of disability, and overall radiography score. Separate multivariable linear regressions were created for each of the features of the developed radiography scoring system. Namely, spondylolisthesis, anterior osteophytes, multiple level disc degeneration, and compete disc space collapse were each correlated to severity of disability, age, BMI and gender. The features of the radiography scoring system were also analyzed for each of the categories of disability - mild, moderate, severe, crippled, and bed-bound. The magnitude of the association was obtained as the correlation coefficient for each of the variables. P value < 0.05 was used as the level of significance. Statistical analysis was carried out using XLSTAT.

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Figure 2: Evaluation of radiographic features of lateral lumbar spine x-rays. A - Arrow indicates anterior osteophytes and a spondylolisthesis between L4/L5. B - Arrows indicate prominent anterior osteophytes at L3/L4 and L4/L5 with degenerative spurring throughout the spine. C - Arrow indicates severe L5/S1 disc degeneration resulting in bone-on-bone contact. D- Evaluation of radiographic features of lateral lumbar.

Results

Of the initial group of 62 patients, 49 were selected for the study (13 patients were removed due to lack of preoperative imaging or lack of BMI information). The mean age was 53.1 years old ± 9.9 years. 24 participants (48.9%) were females. The mean BMI was 29.6 ± 5.3, with 20 (40.8%) obese patients (Table 1).

Variable	All N = 49 n ((n/N)%)
Age	
30 - 39 years	4 (8.16%)
40 - 49 years	31 (63.27%)
50 - 59 years	1 (2.04%)
60 - 69 years	14 (28.6%)
70 - 79 years	1 (2.04%)
Mean age = 53.1; SD = 9.9	
Gender	
Female	24 (49%)
Male	25 (51%)
Body Mass Index (BMI)	
Normal Weight (BMI < = 24.9 and >18)	10 (20.4%)
Overweight (BMI > = 25 and < = 29.9)	19 (36.7%)
Obese (BMI > = 30)	21 (42.9%)
Mean BMI = 29.59; SD = 5.3	

Table 1: Summary of demographic and clinical participant data.

The radiographic scoring system resulted in 19 patients (38.9%) with spondylolisthesis, 28 (57.1%) with anterior osteophytes, 23 (46.9%) with adjacent degeneration in the lumbar spine, and 19 (38.8%) with complete disc space collapse. The mean radiography score was 1.82 ± 1.09 (Table 2).

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Lumbar Spondylolisthesis	
Grade 0	30 (61.22%)
Grade 1	19 (38.88%)
Anterior Osteophytes	
Grade 0	21(42.86%)
Grade 1	28 (57.14%)
Lumbar Adjacent Level Degeneration	
Grade 0	26 (53.06%)
Grade 1	23 (46.94%)
Lumbar Disc Space Collapse	
Grade 0	30 (61.22%)
Grade 1	19 (38.78%)
Mean Score: 1.82; SD = 1.09	

Table 2: *Lumbar Radiography Scoring System: Grading Scale for the Radiographic Features of LDD.*

The patient cohort was also divided into the differing percentiles of disability as described by the ODI. The mean severity of disability was 30.12 ± 9.32 with 1 mildly disabled patient, 7 moderately disabled patients, 21 severely disabled patients, 15 crippled patients, and 8 bed-bound patients (Table 3).

Oswestry Score Stratification	Number of Patients
Mild Disability (0 - 20%)	1
Moderate Disability (20 - 40%)	7
Severe Disability (40 - 60%)	21
Crippled (60 - 80%)	15
Bed-Bound (80 - 100%)	8

Table 3: *Patient disability as defined by ODI.*

The lumbar radiography scores and the disability scores from the ODI did not exhibit correlation with a p value of 0.135 (Figure 3 and Table 4).

P values				
Variables	**BMI**	**Oswestry Score**	**Radiography Score/LDD**	**Age**
BMI	0	0.281	0.582	0.158
Oswestry Score	0.281	0	0.135	0.070
Radiography Score/LDD	0.582	0.135	0	< 0.0001
Age	0.158	0.070	<0.0001	0

Table 4: *Association between BMI, Oswestry score, lumbar radiography score and age - multivariable analysis by linear regression.*

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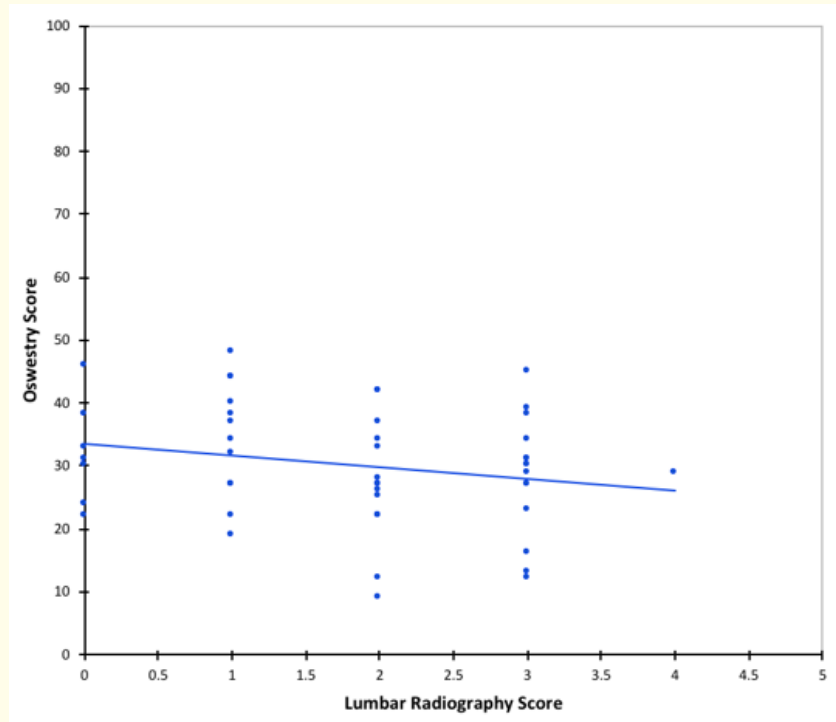
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Figure 3: *Association between lumbar radiography score with disability score as defined by ODI.*

The advancing age was significantly correlated with radiography score with a p value of < 0.0001 (Figure 4, Table 4, Figure 5).
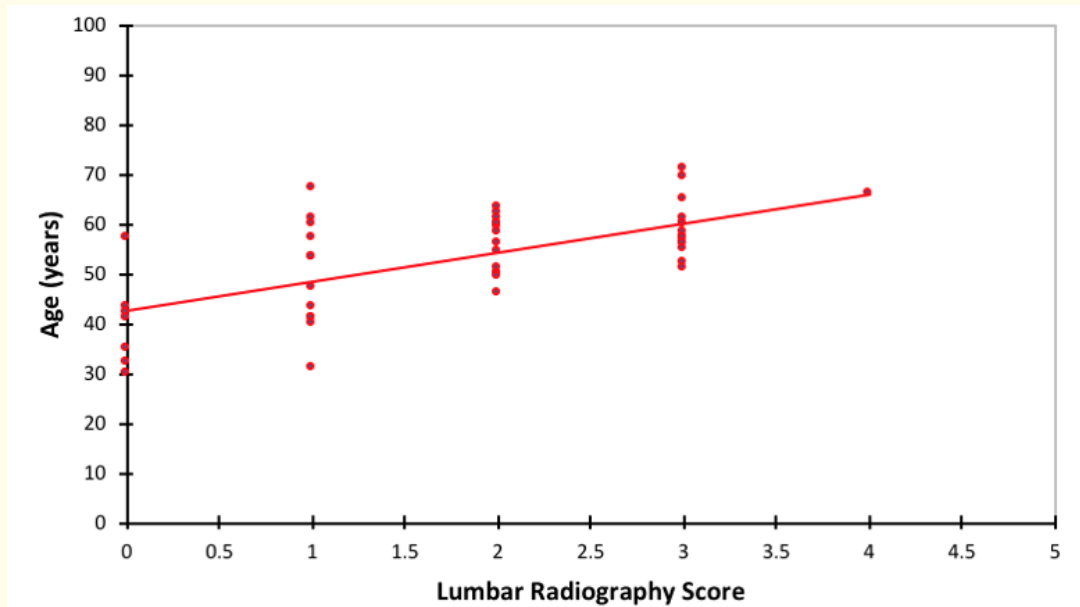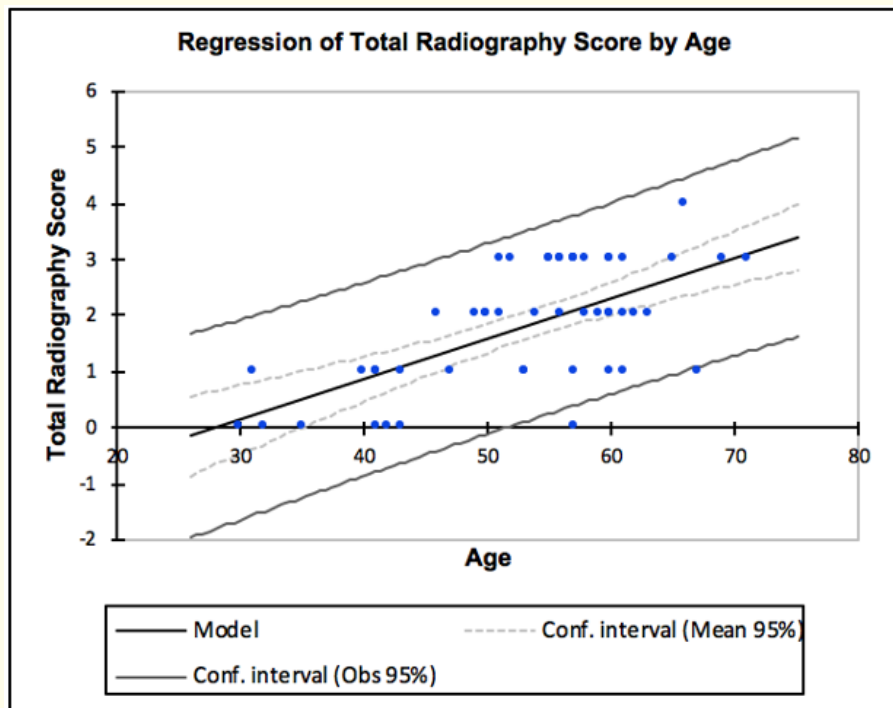

Figure 4: *Association between lumbar radiography score and age.*

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P values				
Variables	**BMI**	**Oswestry Score**	**Radiography Score/LDD**	**Age**
BMI	0	0.281	0.582	0.158
Oswestry Score	0.281	0	0.135	0.070
Radiography Score/LDD	0.582	0.135	0	< 0.0001
Age	0.158	0.070	<0.0001	0

Table 4: Association between BMI, Oswestry score, lumbar radiography score and age - multivariable analysis by linear regression.

Figure 5: Regression of total radiography score by age.

The grading score for listhesis from the radiographic analysis and the disability score from the ODI show correlation with a p value of 0.001 (Figure 6, Table 5, Figure 7).
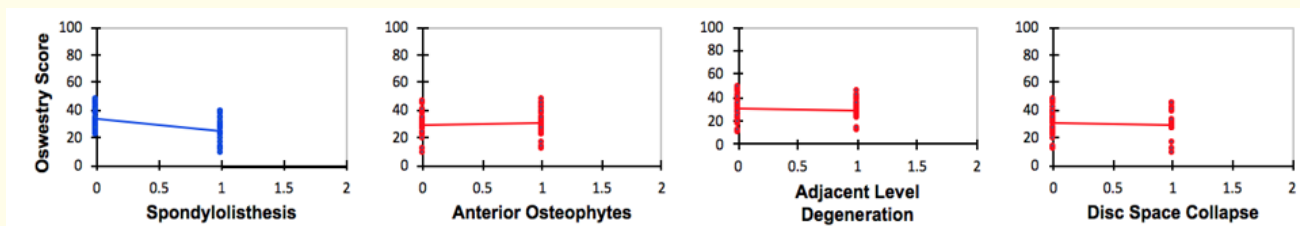
Figure 6: Correlation between the disability score and features of LDD identified in the lumbar radiography score.

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P values	
Variables	**Oswestry Score**
Radiography Score Spondylolisthesis	0.001
Radiography Score Ant. Osteophytes	0.701
Radiography Score Adj. Level Degen.	0.790

Table 5: *Association between radiographic features of LDD and oswestry score - multivariable analysis by linear regression.*
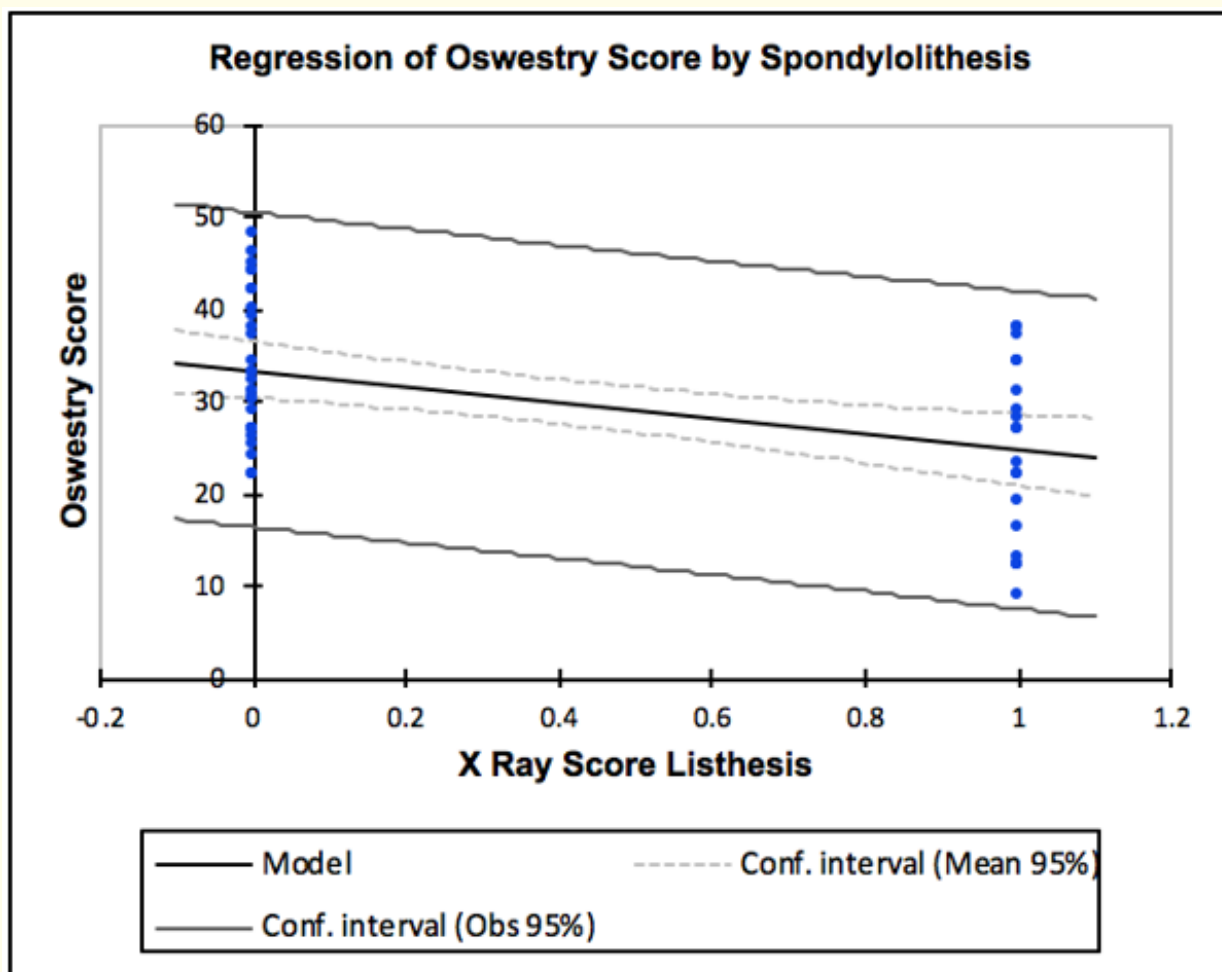

Figure 7: *Regression of oswestry score by spondylolisthesis.*

The total number of patients in the study were subdivided into five disability percentiles as defined by the ODI, in which 0 - 20% represents mild disability, 20 - 40% represents moderate disability, 40 - 60% represents severe disability, 60 - 80% represents bed-bound patients and 80 - 100% represents crippled patients. The four characteristics of LDD examined by the radiography score were then identified in patients in each of the different disability categories. LDD characteristics were found to be most prevalent in patients with severe (40 - 60%) ODI scores, and anterior osteophytes were identified as the most common radiographic feature (Figure 8).
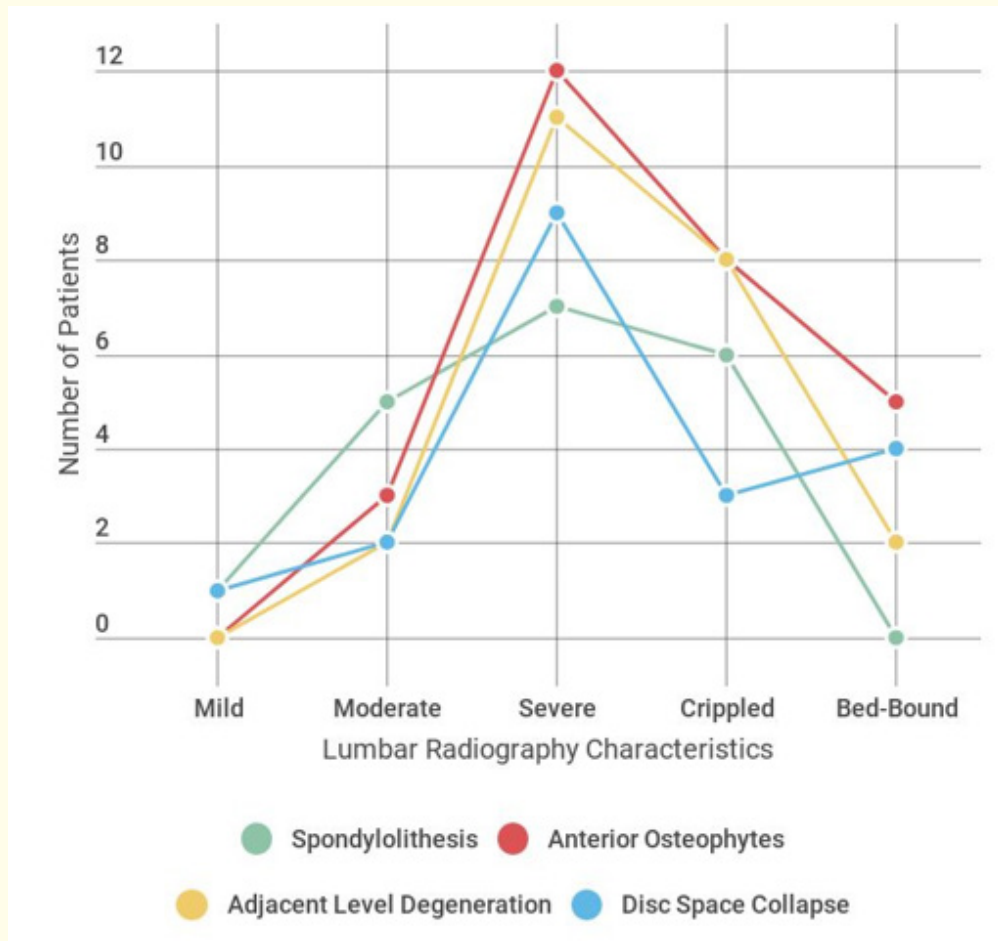
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Figure 8: Association between number of patients with different levels of disability as defined by ODI and lumbar radiography characteristics.

Discussion

The novel lumbar radiography scoring system that was developed provides insight into the need for a more standardized and comprehensive system of evaluating lumbar spine x-ray images. The grading scale that was created to score lumbar images operated on a binary scale for the presence or absence of key features associated with lumbar disc degeneration. Specifically, the radiographic features of LDD that were included in the novel lumbar radiography grading scale were spondylolisthesis, adjacent level disc degeneration, anterior osteophytes, and disc space collapse [13]. These characteristics were selected due to their prominent roles in diagnosis and treatment of mechanical low back pain. The consistency in identifying these features was confirmed through repeated evaluations of lumbar radiography images by trained orthopedic surgeons who were blinded to the researchers' scoring results. Each of these trained physicians, as well as the researchers, achieved the same results.

LDD is the deterioration of the lumbar discs that results in an unequal shift of weight distribution on the spine that often causes low back pain. The hallmark characteristic of disc degeneration is the loss of disc height and ultimately the collapse of the disc space. This in turn increases the abnormal weight distribution that causes the lumbar vertebral bodies to shift from their original placement. An increase in severity of this movement is classified as spondylolisthesis. The compensatory reaction is the formation of osteophytes. Osteophytes is

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the bony growth that appears as spurs in attempt to stabilize the abnormal force distribution from the degeneration of the disc [14]. These features can spread throughout the lumbar spine and this is classified as adjacent level degeneration. Due to the mechanical relevance of these features on LDD diagnosis through radiography, these factors were incorporated into the lumbar radiography grading scale.

The lumbar radiography score was evaluated in the relation to patient age, sex, BMI, and Oswestry Disability Index. Intra-observer reliability of lumbar radiography score was confirmed by repeated evaluations of radiographic images by orthopedic surgeons of varied specialties. The correlation between advancing age and lumbar radiography score had statistical significance, with a p value of less than 0.0001. This finding is consistent with similar studies that correlate age with the severity of LDD, as identified by its signature characteristics in lumbar radiography [3,15]. Because age was not shown to correlate with the severity of disability, advancing age is a potential confounder in this study. Moreover, advancing age is correlated with loss of bone mass that has the potential to increase the severity score of a lumbar radiography image [14]. Future studies would need to be conducted to affirm the relationship between severity of disability due to LDD and advancing age.

The sex of study participants was not correlated with the severity of disability or the severity of lumbar spine radiography images. Previous research has found that women report higher levels of disability due to LDD [15,16]. Furthermore, women have been reported to be at a higher risk for developing spondylolisthesis. This holds significance because this paper identified as association between the presence of spondylolisthesis and the severity of disability. However, alternate studies have identified an increased risk of disability in men for other factors related to LDD [16], or a lack of association between sex and characteristics of LDD that could increase disability [7]. There is no general consensus on the relation between sex and disability.

A defining characteristic of the patient population in the South Bronx is the high rate of obesity. 41% of the population is classified as overweight and 25% is classified as obese [12]. This was reflected in the study cohort with 36.7% classified as overweight and 42.9% classified as obese. The average BMI of this cohort was approximately 30, which is classified as obese. Previous studies have found that a severely overweight BMI acts as a strong risk factor for the severity of LDD, as well as how many discs are affected by degeneration [9]. However, no correlation was identified between BMI and disability. This contradicts previous studies on claims that overweight BMI is a prominent risk factor of LDD. While this finding needs more conclusive validity tests, it offers novel insight on placing less significance on BMI when determining the level of disability due to low back pain. Further studies should conducted with a larger sample size of patients to identify the relationship between BMI and LDD.

In context to the Oswestry Disability Index stratification, patients with severe ODI (40 - 60%) scores were found to have the highest prevalence of the 4 LDD factors. The presence of anterior osteophytes was identified as the most common of the LDD features. It is important to note that there was a greater sample size of patients categorized as severe relative to the remaining categories. The unequal distribution of the ODI stratification may have an influence on the relationship between ODI stratification and prevalence of the LDD features.

The cross-sectional study of lumbar spine radiography score as an indicator for the Oswestry Disability Index did not exhibit significant correlation. This scoring system did not correlate with the ODI for patients who self-reported greater than 60% on the ODI. However, there was evidence of correlation between the presence of spondylolisthesis and an increase in the disability score from the Oswestry Disability Index. The additional three features of the novel radiography scoring system - anterior osteophytes, adjacent level degeneration of the lumbar spine, and disc space collapse - did not show a correlation to the patients' overall level of disability. These results are suggestive of the presence or absence of spondylolisthesis as a driving force in patient disability level, as displayed in figure 8. Future iterations of this radiography score have the potential to determine the relationship between lumbar radiography characteristics that cause clinical symptoms of disability.

This study is limited by the small sample size of low back pain patients and the uneven distribution of the patient cohorts between the five ODI disability categories. Patients in the severe disability category were identified with the greatest prevalence of LDD radiographic factors, but the pool of patients with severe disability made up nearly 43% of the total group. In addition, this study is limited by the lack of inclusion of alternate clinical factors (i.e. smoking history) that may influence a patient's level of disability due to pain or the progression of LDD.

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Another limiting factor of this study was the small numeric range of the lumbar radiographic scoring system. Each of 4 radiographic features of LDD were given a score range from 0-1, indicating the presence or absence of each feature. However, it is widely known that these features such as anterior osteophytes have varying grades of severity. The absence of a detailed numeric range have influenced the validity of the lumbar radiographic scoring system.

Future studies should be conducted to modify this lumbar radiography scale in order to standardize the association between radiographic features of LDD with level of low back pain disability. In addition, further investigations of the associations between advancing age and disability, sex and disability, and BMI and disability should be conducted.

Conclusion

This study highlights the need to gather further data on the correlation between radiographic evidence of LDD and disability among patients with low back pain. This scoring system acts as a preliminary protocol to standardize radiographic ratings of LDD, which needs to be further refined. The presence of spondylolisthesis and advancing age serve as strong indicators of increased disability, which can thus be used to diagnose patients and generate adequate treatment plans.

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