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Spondylolysis and spondylolisthesis: prevalence and association with low back pain in the adult community-based population

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Abstract

Study Design—Cross-sectional study.

Objectives—1) to determine prevalence rates of spondylolysis, isthmic and degenerative spondylolisthesis in an unselected adult community-based population; 2) to evaluate the association of spondylolysis, isthmic and degenerative spondylolisthesis with low back pain (LBP).

Summary of Background Data—Spondylolysis and spondylolisthesis are prevalent in the general population; however the relationship between these conditions and LBP is controversial.

Methods—This study was an ancillary project to the Framingham Heart Study. A sample of 3529 participants of the Framingham Heart Study aged 40–80 years underwent multi-detector CT imaging to assess aortic calcification. 188 individuals were consecutively enrolled in this study to assess radiographic features potentially associated with LBP. The occurrence of LBP in the preceding 12 months was evaluated using a self-report questionnaire. The presence of spondylolysis and spondylolisthesis was characterized by CT imaging. We used multiple logistic regression models to examine the association between spondylolysis, spondylolisthesis and LBP, while adjusting for gender, age and BMI.

Results—21 study subjects demonstrated spondylolysis on CT imaging. The male-to-female ratio was approximately 3:1. 21% of subjects with bilateral spondylolytic defects demonstrated no measurable spondylolisthesis. The male-to-female ratio of degenerative spondylolisthesis was 1:3, and the prevalence of degenerative spondylolisthesis increased from the fifth through eight decades of life. 38 subjects (20.4%) reported significant LBP. No significant association was identified between spondylolysis, isthmic spondylolisthesis, or degenerative spondylolisthesis, and the occurrence of LBP.

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Conclusions—Based on CT imaging of an unselected community-based population, the prevalence of lumbar spondylolysis is 11.5%, nearly twice the prevalence of previous plain radiograph-based studies. This study did not reveal a significant association between the observation of spondylolysis on CT and the occurrence of LBP, suggesting that the condition does not appear to represent a major cause of LBP in the general population.

Introduction

Lumbar spondylolysis and spondylolisthesis are often identified in the course of clinical evaluation of patients with low back pain (LBP). Spondylolysis is an anatomic defect in the vertebral pars interarticularis and is most commonly observed in the lowest lumbar vertebrae. Spondylolisthesis refers to displacement of a vertebral body on the one below it and has several etiologies, the most common being spondylolysis and spondylotic degeneration. Both spondylolysis and spondylolisthesis are prevalent in the general population, including a relatively high percentage of asymptomatic individuals; therefore, the relationship between these conditions and clinically significant LBP has been a subject of ongoing controversy.

Previous population-based studies have consistently suggested that lumbar spondylolysis demonstrates a prevalence in the adult population of 6% [1, 2]. It has been estimated that 25% of individuals with spondylolysis experience at least one episode of significant back pain at some point in their lifetime. Individuals engaged in specific athletic activities such as football, gymnastics, wrestling, volleyball, and weightlifting appear more likely to develop symptomatic LBP associated with spondylolysis [3, 4].

The two major etiologies of spondylolisthesis are “isthmic” associated with spondylolysis and “degenerative” associated with degeneration of the posterior facet joints and/or intervertebral disc. Degenerative spondylolisthesis occurs mostly at the L4-5 level [5, 6] as opposed to isthmic spondylolisthesis, which occurs most often at the lumbosacral level (L5-S1) [7]. Isthmic spondylolisthesis appears in a majority of individuals with spondylolysis. 68% of first-graders with spondylolysis have been shown to have associated isthmic spondylolisthesis (Fredrickson et al. 1984). In another study, 80% of children with LBP and spondylolysis were found to have associated isthmic spondylolisthesis [8, 9].

Given ongoing uncertainty regarding the true relationship between spondylolysis, spondylolisthesis, and development of LBP, evaluation and treatment patterns for these conditions remains highly varied. Initial attempts at conservative management are recommended and typically include a combination of activity modification, nonsteroidal anti-inflammatory medication, and physical therapy. Although there is some evidence that these patients respond similarly to patients without spondylolysis or spondylolisthesis, data regarding long-term clinical outcomes is lacking [10]. Both diagnostic and therapeutic injections of the pars defect or local lumbar nerve root are frequently performed, but no clinical data regarding the utility of these measures has been reported. Indications for surgical treatment of these patients remain highly controversial.

A major deficit in current knowledge regarding the relationship between spondylolysis, spondylolisthesis, and LBP is the absence of reliable epidemiologic data investigating all three factors in an unselected community-based population. Previous studies have consisted almost entirely of radiographic reviews. In all cases, these studies either made no attempt to correlate radiographic findings with clinical symptoms or were derived from highly selected patient populations, i.e. patients presenting to a clinic for treatment of back pain. Moreover, the use of plain radiographs in these studies is highly problematic.

Computed tomography (CT) is currently considered the most accurate imaging modality for the identification of spondylolysis and often reveals the presence of non-displaced spondylolysis when plain radiographs appear normal [11, 12].

The aims of the present study were: 1) to evaluate the prevalence of spondylolysis, isthmic and degenerative spondylolisthesis in different age groups and at different lumbar spinal levels and according to sex in an adult community-based population; 2) to evaluate the association of spondylolysis, isthmic and degenerative spondylolisthesis with LBP in the same community-based cohort.

Methods

Study design

Cross-sectional study.

Sample

This project was an ancillary project to the Framingham Heart Study. The Framingham Heart Study began in 1948 as a longitudinal population-based cohort study of the causes of heart disease. Initially, 5209 men and women between the ages of 30 and 60 years living in Framingham, Massachusetts were enrolled. All subjects underwent biennial examinations. In 1971, 5,124 offspring (and their spouses) of the original cohort were entered into the Offspring cohort. In 2002, 4095 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 [13, 14]. 3529 participants of the Framingham study (participants in both the Offspring and Third Generation cohorts) aged 40–80 years underwent abdominal and chest multi-detector CT scanning to assess coronary and aortic calcification. The recruitment and conduct of CT scanning have been previously reported [15, 16]. During the CT study, 188 participants were consecutively enrolled in this ancillary study to assess the association between CT-observed characteristics of the lumbosacral spine and LBP.

LBP evaluation

All study participants undergoing multi-detector CT scan were asked to complete the modified Nordic Low Back Questionnaire [17]. 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’ answers “yes” or “no” on the above question, were used in the present study as the back pain outcome (dichotomous index). Similar methods are widely used in studies of work related low back pain [18–20].

Imaging parameters

Study participants were imaged with an eight-slice multi-detector CT scanner (Lightspeed Ultra, GE, Milwaukee, WI, USA). Each subject underwent unenhanced abdominal multi-detector CT performed using a sequential scan protocol with a slice collimation of 8 mm × 2.5 mm (120 KVp, 320/400 mA for 220 lbs body weight, respectively) during a single end-inspiratory breath hold. For the abdominal scan, thirty contiguous 5 mm thick slices of the abdomen were acquired covering 150 mm above the level of S1.

The evaluation of all spinal degeneration parameters in this study was performed using eFilm Workstation (Version 2.0.0) software.

Spondylolysis and spondylolisthesis evaluation

CT scans were evaluated in blinded fashion with respect to clinical and personal data. The entire lumbar spine was reviewed for each case, using bone windows. Both axial views and multiplanar reconstruction were analyzed (Figure 1). On CT scan, spondylolysis is well demonstrated as a linear lucidity or defect extending through the pars interarticularis. This is easily recognized on sagittal 2D reconstructions. Spondylolysis was marked as present or absent at right or left sides of the lumbar vertebrae or bilateral. In the case where the image review was equivocal, it was evaluated again by two readers. CT evaluation of spondylolysis, especially using multiplanar reconstruction has previously been described as reliable and accurate method [11, 12].

Grading (I to IV) of spondylolisthesis (Meyerding [21] classification) was estimated using sagittal reformations. Spondylolisthesis identified at a spinal segment with bilateral spondylolysis was considered isthmic spondylolisthesis. Spondylolisthesis observed in the absence of spondylolysis was considered degenerative spondylolisthesis. There were no individuals with spondylolisthesis associated with unilateral spondylolysis in the studied sample.

Reliability of CT readings

All readers were trained by an experienced research musculoskeletal radiologist (AG). An initial set of CTs were analyzed to develop a reading protocol for evaluation of spondylolysis and spondylolisthesis derived from the Meyerding classification. Using this protocol, the intra- and inter-rater reliability was calculated for two readers. All CT scans were then analyzed in blinded fashion. To evaluate for reader-drift, intra-rater reliability was periodically reassessed by inserting one repeated “reliability” scan for every 10 new scans. Before analyzing each new set of CT scans, 5 previously analyzed CTs were reevaluated to “recalibrate” the readings to a standard. The intra-observer reliability for identification of spondylolysis was 1.00. The inter-observer reliability was 0.98. For spondylolisthesis the intra-observer reliability varied at different levels between 0.95 and 1.00, and the inter-observer reliability ranged from 0.75 to 0.98. This range of kappa statistics represents good to excellent reproducibility.

Body mass index (BMI)

BMI was computed as the ratio of weight (in kg) divided by height (in square meters).

Statistical Methods

The prevalence of spondylolysis, isthmic and degenerative spondylolisthesis at different spinal levels, in five different age groups (<40, 40–49, 50–59, 60–69, ≥70 years) and in both sexes was calculated. Those prevalence estimations were compared using Chi-square test or Fisher’s exact test.

Multiple logistic regression model was used to examine the association between LBP and spondylolysis, isthmic and degenerative spondylolisthesis, while adjusting for gender, age and BMI. The prevalence of those studied conditions in subjects with and without LBP was also compared. All statistical analyses were performed using SAS software, (SAS Institute Inc, Cary, North Carolina, release 9.1).

Results

Table 1 lists the demographic characteristics of the 188 study participants. The mean age was 52.66±10.79 (age range: 32–79). The mean BMI was 27.84±5.03. The study sample included 104 males and 84 females.

Lumbar Spondylolysis

21 of 188 subjects (11.5% of study population) demonstrated lumbar spondylolysis on CT. Two subjects demonstrated unilateral spondylolytic defects while the remaining subjects were found to have bilateral defects; and one man had spondylolysis at two spinal levels, L4-L5 and L5-S1.

Table 2 shows the prevalence of spondylolysis by spinal level in males, females and in the total sample. The highest prevalence was found at the L5 spinal level (13.6% in males, 2.5% in females and 8.6% in the whole study sample). Males demonstrated a significantly greater prevalence of spondylolysis compared to females (16.5% vs. 5.0%, p=0.0154). We found no difference in prevalence of spondylolysis between different age groups in males (p=0.104), females (p=0.464) and in total sample (p=0.342). Chi-square test demonstrated statistically significant sex difference in prevalence of spondylolysis (p=0.0354), with almost three times higher prevalence among males.

Spondylolisthesis

Spondylolisthesis was identified in 39 subjects, that is 20.7% of the studied population. 15 of 19 (79.0%) individuals with bilateral spondylolysis had associated spondylolisthesis. The prevalence of isthmic spondylolisthesis in our community-based sample was 8.2%. Spondylolysis in the absence of spondylolisthesis was found to be relatively uncommon. 4 of 19 subjects with bilateral spondylolysis (21.1%) demonstrated no measurable spondylolisthesis. One man demonstrated spondylolysis at two spinal levels, L4-L5 and L5-S1; but associated spondylolisthesis was observed only at the lower spinal level (L5-S1).

Table 3 shows the prevalence of isthmic spondylolisthesis by spinal level in males, females and in the total population. In the studied community-based sample 15 (8.2%) individuals had isthmic spondylolisthesis, among them 11 (10.6%) men and 4 (5.0%) of women. The highest prevalence of isthmic spondylolisthesis was found at the L5-S1 spinal level (8.7%, 2.5% and 5.9%, respectively). No statistically significant differences were found in prevalence of isthmic spondylolisthesis between age groups in males (p=0.862), females (p=0.464) and in total population (p=0.916). No difference in prevalence of isthmic spondylolisthesis between sexes was found.

23 of 165 (13.9%) individuals without spondylolysis had spondylolisthesis. Table 4 shows the prevalence of degenerative spondylolisthesis by spinal level in males, females and in the total sample. Degenerative spondylolisthesis was found in 25 (13.6%) study participants, 8 (7.7%) men and 17 (21.3%) women. In contrast to isthmic spondylolisthesis, the highest prevalence of degenerative one was found at the L4-L5 level (5.9% in total sample), following by L5-S1 level (5.4%). By decade, degenerative spondylolisthesis was present in (0) 0% of <40-years-olds; (1) 2.1% of 40–49-years-olds, (7) 10.8% of 50–59-years-olds, (15) 41.7% of 60–69-years-olds, and (2) 16.7% of ≥70-years-olds (Figure 2). The differences between age groups were highly significant, p=<0.0001 in total sample. Prevalence of degenerative spondylolisthesis was significantly higher in women than in men (p=0.008).

Low Back Pain

Overall, 38 of 188 subjects (20.2% of the study population) reported significant LBP. Table 5 shows the comparison of prevalence of spondylolysis, isthmic and degenerative spondylolisthesis between groups of individuals with and without LBP. No significant association was identified between any of the studied conditions, spondylolysis, isthmic or degenerative spondylolisthesis and the occurrence of LBP.

Table 6 shows the results of multiple logistic regression analysis where LBP was a dependent variable and spondylolysis, isthmic and degenerative spondylolisthesis at any spinal level, sex, age groups and BMI were included as independent variables. There were no statistically significant associations found between LBP and aforementioned predicting variables (p-value >0.05 for each association).

Discussion

The major finding of this study is a much higher prevalence of lumbar spondylolysis in the general population than previously reported. The 11.3% rate identified is nearly double the 6% rate that has been generally believed to be true based on previous epidemiologic studies [1, 2]. According to these earlier studies, most cases of spondylolysis arise in early childhood, and 4.4% of children entering first grade have spondylolysis on screening plain radiographs [1, 22]. It has been thought that the prevalence increases to 6% by age 18 and remains stable at that rate throughout adulthood.

A likely explanation for the significantly higher rate identified in the current study is the use of computed tomography. This advanced imaging modality is currently considered the gold standard in terms of identifying spondylolysis, particularly in the setting of unilateral defects, non-displaced bilateral defects, and chronic cases that may be relatively quiescent on nuclear medicine studies. The use of advanced imaging of any kind is unique to this study, as is the utilization of an unselected community-based study population, in this case derived from the Framingham Heart Study population. All previous studies of spondylolysis prevalence, including the oft-cited Scandinavian population study by Virta et al. [2] have reported data from large screening programs based solely on plain radiographs.

Rates of spondylolysis have been shown to vary by ethnic group. For example, both clinical studies and specimen studies have suggested that the prevalence of spondylolysis in the Native American and Eskimo populations is quite high and ranges from 17 to 53% [23, 24]. Although ethnic variation is a possible contributing factor to the increased prevalence rates observed, it is unlikely to be the major factor. The Framingham Heart Study cohort has been shown to be a representative American population in terms of genealogy and the ethnic makeup should be comparable to those used in the studies of Fredrickson et al. [1] and Baker and McHolick[18] which also reported a 6% prevalence rate but also utilized plain radiographic imaging.

Additional findings of this study support epidemiologic patterns previously reported and include a significant male predominance in terms of both, spondylolysis and isthmic spondylolisthesis as well as a trend favoring females in terms of the prevalence of degenerative spondylolisthesis. In the present study we found that males had statistically significantly higher prevalence of spondylolysis (p=0.0354). The male-to-female ratio of almost 3:1 in the current study is just slightly higher than 2:1 ratio reported in other studies [25–29]. Women demonstrated a significantly higher prevalence of degenerative spondylolisthesis compared to men (p=0.008), with a male-to-female ratio of 1:3. These results are also in agreement with those previously reported [30–32]. The vast majority of spondylolysis cases involved the L5 vertebral level (male 13.6%, female 2.5%, total 8.6%), as previously shown, and degenerative spondylolisthesis was most commonly observed at the L4-5 level (male 3.9%, female 8.8%, total 5.9%). The 21% rate of bilateral spondylolysis without any measurable spondylolisthesis is noteworthy and reinforces the point that these lesions may easily be missed by standard biplanar plain radiographic evaluation.

Despite the small sample size of our pilot study, the strength of it is that we have an unselected community sample that is part of Framingham Heart Study. If this prevalence rate were confirmed in CT studies in other population based samples, it can have far-reaching implications in terms of clinical care of back pain patients. For example, the higher the prevalence of spondylolysis, the greater the potential that it represents an incidental finding in patients being evaluated for chronic LBP, and the less likely that surgical treatment directed at the spondylolysis will be successful.

As expected, the prevalence of degenerative spondylolisthesis showed a statistically significant increase through older age groups in males (p=0.003), females (p=0.001) and in total sample (p=<0.0001). No cases of degenerative spondylolisthesis were observed in men less than 40 years, nor in women less than 50 years of age. The highest prevalence of degenerative spondylolisthesis was observed in the 60–69 year age group with a lower prevalence observed in individuals older than 70. Our findings are in accordance with the results of the Copenhagen Osteoarthritis Study [32] that also showed that degenerative spondylolisthesis was significantly associated with increased age in both sexes. In this study very few individuals (about 4% of all degenerative spondylolisthesis cases) had spondylolisthesis at L4-L5 level prior to age 50. This was a plain radiographic study where the films were obtained in an upright position although it is unclear what percentage of the participants with degenerative spondylolisthesis younger than 50 were female. Most investigators believe that spinal alignment changes when imaging is obtained in the supine versus upright position. The effects of gravity as well as postural muscles can increase or decrease any spondylolisthesis that is present. In an age group of 51 to 60 about 14% and in an age group 61 to 70 about 52% of degenerative spondylolisthesis cases occurred.

In this study, no statistically significant associations were found between spondylolysis, isthmic and degenerative spondylolisthesis and the occurrence of LBP. Currently, the relationship between spondylolysis, spondylolisthesis and LBP remains controversial. Reported studies have failed to produce conclusive data indicating that spondylolysis in the general population represents a major cause of LBP. Pathologic mobility of the separated so-called “Gill fragment” of the spinal lamina is considered to be one of the sources of LBP, but in many cases, the presence of spondylolysis or isthmic spondylolisthesis was identified incidentally in asymptomatic patients [1, 33–38]. One recent histomorphological study [39] of surgically retrieved specimens found that spondylolysis appears as a pseudarthorosis of the pars interarticularis and the region around the spondylolysis tends to develop non-innervated ligament-like tissue with an enthesis structure that appears to demonstrate no histological correlate to chronic LBP.

The clinical presentation of spondylolisthesis is quite variable and is not well correlated with the degree of deformity or degenerative changes [40]. Pain with concurrent symptomatic spinal stenosis is the most characteristic presentation of degenerative spondylolisthesis. The absence of a significant correlation in this study suggests that it may not actually be a major source of LBP in the general population. Alternatively, these findings may again be due to the relatively small sample size.

Conclusion

The findings of this study suggest a significantly higher prevalence of lumbar spondylolysis in the general US population than previously reported. The 11.5% prevalence in an unselected community-based population based on computed tomography imaging is nearly twice the prevalence reported by previous plain radiograph based studies. This high prevalence rate carries potentially broad implications with respect to appropriate evaluation and treatment of individuals presenting with low back pain in the setting of spondylolysis.

Although likely underpowered to detect a small population effect, this study did not reveal a significant association between the observation of spondylolysis and spondylolisthesis on CT and the occurrence of LBP, suggesting that these conditions does not appear to represent a major cause of LBP in the general population.

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Key points

- The prevalence of lumbar spondylolysis in an unselected community-based population is 11.5%, nearly twice the prevalence of previous plain radiograph-based studies.
- The prevalence of degenerative spondylolisthesis showed a statistically significant increase with age.
- Male-to-female ratio in the studied sample was 3:1 for spondylolysis, 2:1 for isthmic spondylolisthesis and 1:3 for degenerative spondylolisthesis.

No significant association was found between the observation of spondylolysis, degenerative or isthmic spondylolisthesis on CT and the occurrence of LBP

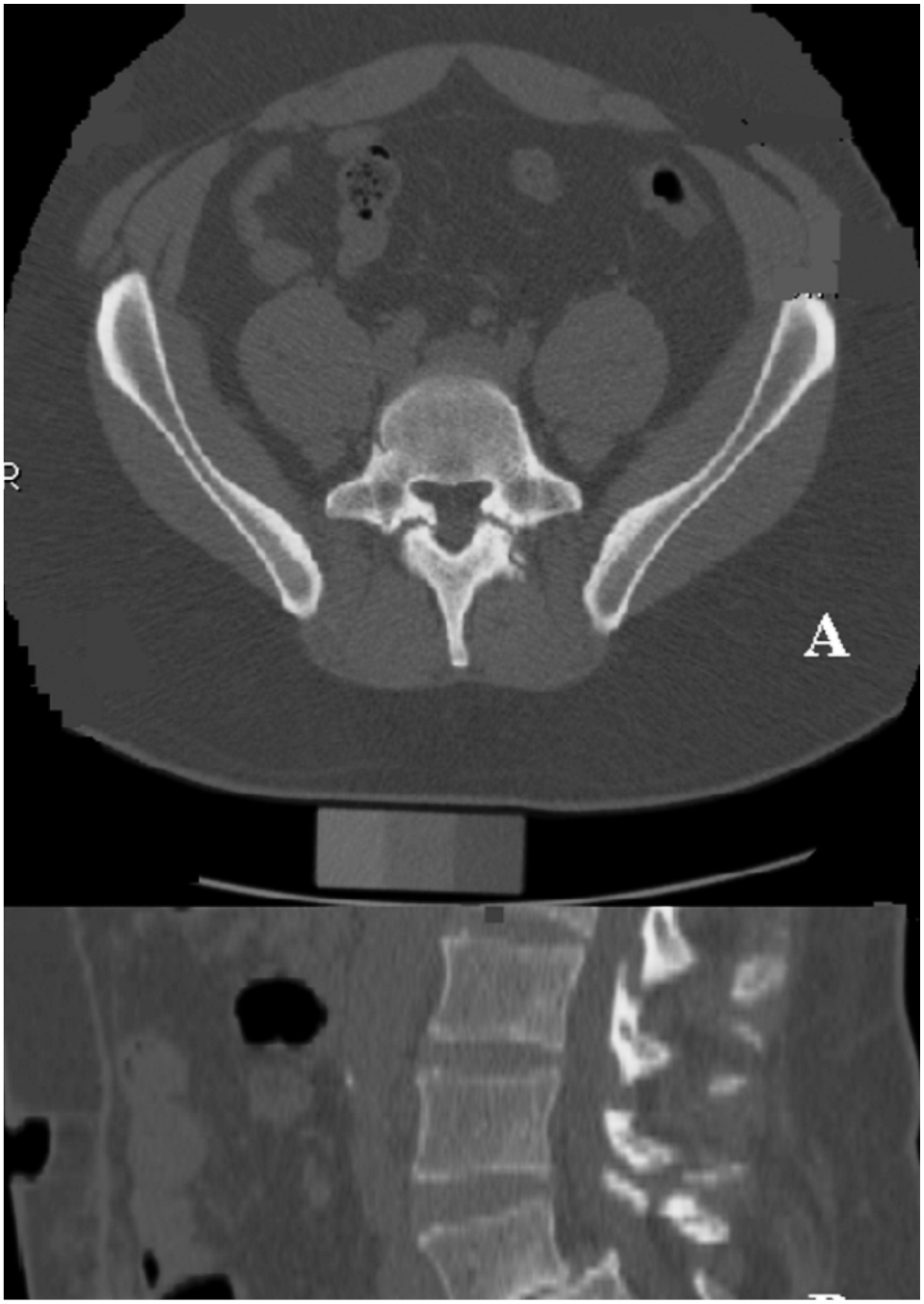

Figure 1.
Examples of evaluated CT images: a) Spondylolysis of L5 is shown on axial views image; b) grade II isthmic spondylolisthesis is shown on sagittal reformatted image.

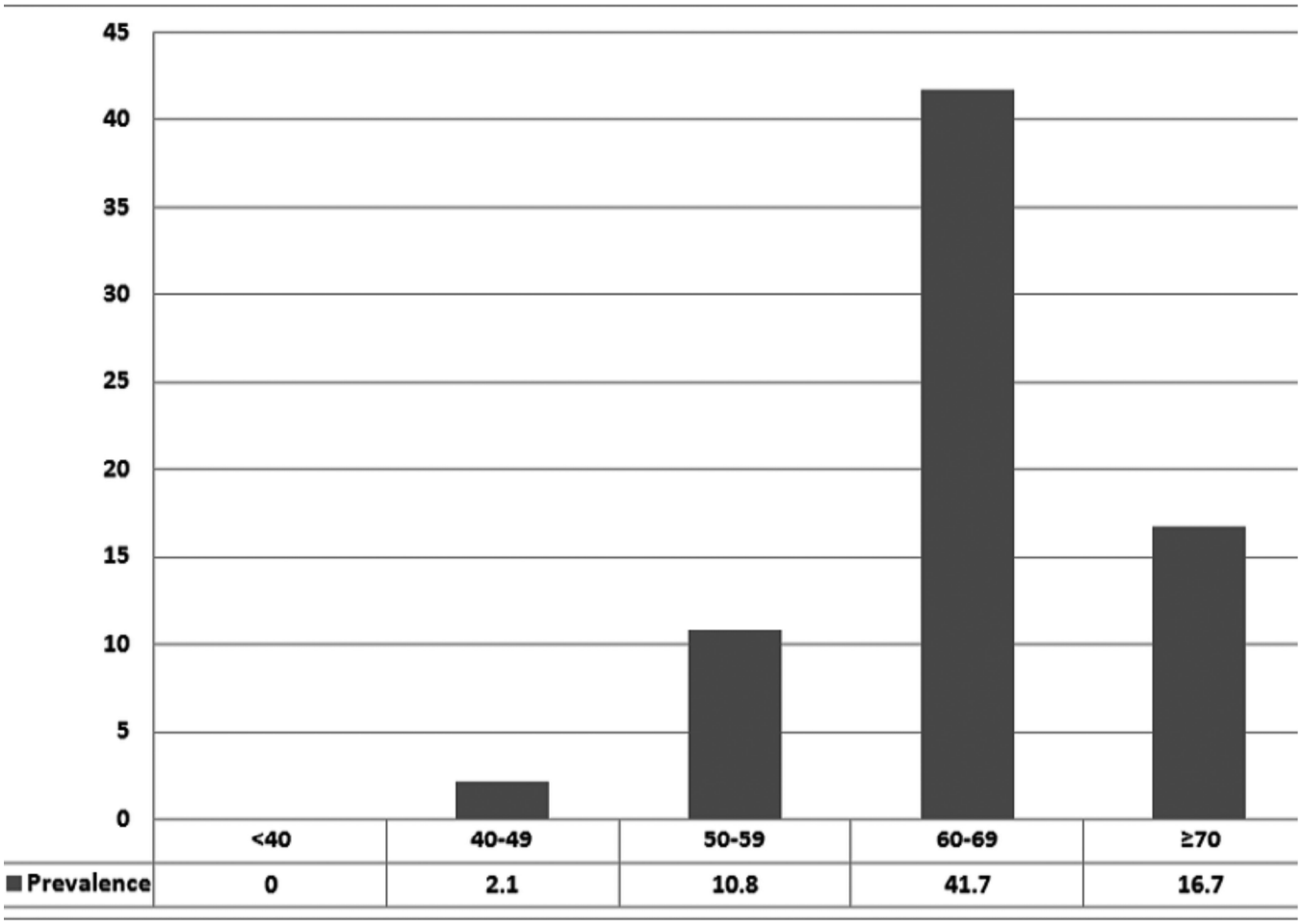

Figure 2.
Change in prevalence of degenerative spondylolisthesis with age.

Table 1

Descriptive statistics of the studied sample.

Variables		Frequencies (%)
N		188
Sex (females)		84 (44.68%)
LBP		38 (20.21%)
Spondylolysis	Unilateral	2 (1.09%) (95%CI 0.13%, 3.89%)
	Bilateral	19 (10.38%) (95%CI 6.37% 15.74%)
Spondylolisthesis		39 (21.2%) (95%CI 15.53% 27.82%)
		Mean values
Age ±SD(years)		52.66(±10.79)
BMI ±SD (kg/m^2)		27.84(±5.03)

Spine (Phila Pa 1976). Author manuscript; available in PMC 2013 October 09.

Table 2

The prevalence of spondylolysis by spinal level and sex.

Spinal level	Males		Females		Total sample		χ2-test (males vs. females by level)
	N	%	N	%	N	%	
L2	0	0	0	0	0	0	-
L3	0	0	1	1.3	1	0.5	P=0.4372
L4	3	2.9	1	1.3	4	2.2	P=0.6329
L5	14	13.6	2	2.5	16	8.6	**P=0.0084**
All levels	17	16.5	4	5.0	21	11.5	**P=0.0154**
χ^2**-test (spinal levels)**	**P<0.0001**		P=0.9045		**P<0.0001**		

Statistically significant at level p<0.05 marked bold.

Table 3

The prevalence of isthmic spondylolisthesis by spinal level and sex.

spinal level	Males		Females		Total sample		χ2-test (males vs. females by level)
	N	%	N	%	N	%	
L2-L3	0	0	0	0	0	0	-
L3-L4	0	0	1	1.3	1	0.5	P=0.4348
L4-L5	2	1.9	1	1.3	3	1.6	P=1.0000
L5-S1	9	8.7	2	2.5	11	5.9	P=0.1171
χ^2-test (spinal levels)	**P<0.0001**		P=0.9045		**P<0.0001**		
All levels	11	10.6	4	5.0	15	8.2	P=0.1705

Statistically significant at level p<0.05 marked bold.

Table 4

The prevalence of degenerative spondylolisthesis by spinal level and sex.

spinal level	Males		Females		Total sample		χ2-test (males vs. females by level)
	N	%	N	%	N	%	
L2-L3	0	0	0	0	0	0	-
L3-L4	0	0	4	5.0	4	2.1	**P=0.0342**
L4-L5	4	3.9	7	8.8	11	5.9	P=0.2137
L5-S1	4	3.9	6	7.5	10	5.4	P=0.3349
All levels	8	7.7	17	21.3	25	13.6	**P=0.0078**
χ^2-test (spinal levels)	**P=0.0313**		**P=0.0334**		**P<0.0001**		

Statistically significant at level p<0.05 marked bold.

Table 5

The prevalence of spondylolysis, isthmic and degenerative spondylolisthesis in individuals with and without LBP.

Variable**	With LBP (n=38)	Without LBP (n=148)	p-value*	OR	95% CI OR
Spondylolysis	5(13.5%)	16(10.7%)	p=0.574	1.299	(0.443, 3.809)
IS	4(10.8%)	11(7.3%)	p=0.502	1.532	(0.459, 5.114)
DS	6(16.2%)	19(12.7%)	p=0.592	1.335	(0.492, 3.620)

Table 6

Results of the multiple logistic regression analysis. LBP (Yes vs. No) was a dependent variable.

Parameter	Odds Ratio Estimates		P-value
	Point Estimate	95% Wald Confidence Limits	
Spondylolysis (Yes vs. No)	0.796	(0.081, 7.787)	0.8443
DS (Yes vs. No)	0.916	(0.287, 2.928)	0.8830
IS (Yes vs. No)	2.393	(0.197, 29.072)	0.4935
Sex (Female vs. Male)	1.487	(0.671, 3.297)	0.3285
Age group 70+ (vs. <40)	0.958	(0.146, 6.296)	0.9491
Age group 60–69 (vs. <40)	1.257	(0.296, 5.334)	0.5966
Age group 50–59 (vs. <40)	1.863	(0.545, 6.367)	0.0560
Age group 40–49 (vs. <40)	0.443	(0.099, 1.975)	0.0893
BMI	1.040	(0.970, 1.117)	0.2709