International Journal of
Rheumatic Diseases

International Journal of Rheumatic Diseases 2017

ORIGINAL ARTICLE

Chronic low back pain and its association with lumbar vertebrae and intervertebral disc changes in adults. A case control study

Aranjan L. KARUNANAYAKE,[1] Arunasalam PATHMESWARAN[2] and Lalith S. WIJAYARATNE[3]

Departments of [1]Anatomy, [2]Public Health, Faculty of Medicine, University of Kelaniya, Ragama, and [3]National Hospital, Colombo, Sri Lanka

Abstract

Aim: This study was done to determine the association between chronic low back pain and vertebral fractures, intervertebral disc space (IDS) narrowing, vertebral osteophytes and spondylolisthesis among adults.

Method: This case control study was done in Sri Lanka. Cases were patients with low back pain and controls were without low back pain. Postero-anterior and lateral radiographs of lumbar sacral spine of both groups were studied. To detect vertebral fractures in fourth and fifth lumbar vertebrae, anterior and posterior heights of vertebrae were measured using a Vernier caliper and antero-posterior ratio (A/P) was calculated. Having an A/P ratio value of < 0.89 was considered as a vertebral fracture. Presence of disc space narrowing, vertebral osteophytes and spondylolisthesis was assessed by two radiologists working independently. Bivariate and logistic regression analysis was done to find associations.

Results: There were 140 cases and 140 controls. Mean (SD) age for cases was 51.6 (17) years. Mean (SD) age for controls was 50 (15) years. Females made up 62% of cases and controls. Fifth lumbar vertebral fracture (odds ratio [OR] = 10.2; $P = 0.001$), fourth lumbar vertebral fracture (OR = 2.5; $P = 0.017$) and IDS narrowing (OR = 4.15, $P = 0.009$) had a significant association with low back pain and vertebral osteophytes and spondylolisthesis did not have a significant association with low back pain.

Conclusion: Only vertebral fractures and IDS narrowing had a significant association with chronic low back pain.

Key words: degeneration, intervertebral disc, low back pain, spondylolisthesis, vertebral fractures, vertebral osteophytes.

INTRODUCTION

Low back pain (LBP) is defined as pain or stiffness in the region between the costal margin and the inferior gluteal folds with or without pain radiating along the lower limbs.[1] Approximately 80% of Americans experience at least one episode of LBP during their lifetime.[2] Wide practice variations still exist in the diagnosis and treatment of low back pain.[3] Non-specific LBP is the most common form of LBP.[4] LBP is thought to be multifactorial in origin with a broad range of risk factors.[5] The most common type of LBP is the mechanical type and the causes for this type are injuries and age-related changes of the vertebrae, intervertebral discs, ligaments and muscles.[6]

Osteoporosis is the main cause of low-energy vertebral fractures in aging populations.[7] Osteoporotic

Correspondence: Dr Aranjan L. Karunanayake, Department of Anatomy, Faculty of Medicine, University of Kelaniya, Ragama, 11010, Sri Lanka.
Emails: aranjan1368@gmail.com; aranjan@kln.ac.lk

vertebral fractures affect a large number of women and men over 50 years of age.[8] Wedge is the commonest type of vertebral fracture.[9] Vertebral fractures are associated with back pain, physical deformity, loss of self-esteem, impaired quality of life and increased morbidity and mortality.[8] One-third of all vertebral fractures are never clinically diagnosed due to symptoms being absent or missed.[10] Although osteoporotic vertebral fractures may pass unnoticed, they may lead to long-term immobility and disability.[11] Dual energy X-ray absorptiometry (DEXA) method measures bone mineral density (BMD). Many studies have reported a weak correlation between bone fracture risk and BMD.[12] Geometrical parameters of vertebrae measured on spine radiograms could be used to diagnose vertebral fractures.[13]

Lumbar spine degenerative changes are common with increase in age. Typical degenerative changes in the spine are intervertebral disc space narrowing and vertebral osteophytes.[14] In addition to causing LBP, intervertebral disc space narrowing can also cause sciatica and abnormal movements of the spine.[15] Antero-posterior and lateral radiographs are used to detect features of degenerative disc disease.[14]

Vertebral osteophytes are bony projections which extend from the rim of the vertebral body. Posterior vertebral osteophytes can cause narrowing of the vertebral canal and also impinge on nerve roots and cause LBP and sciatica.[16]

Spondylolisthesis is defined as a migration of a vertebral body in relation to the vertebra located immediately inferior. The symptoms associated with spondylolisthesis are LBP, numbness and weakness in the legs.[17]

Frequent identification of radiographic abnormalities influence medical decision-making with regard to additional evaluation and selection of treatment options. Although MRI is the imaging modality of choice, in the primary care settings, the most common spine imaging test for assessing LBP is plain film radiographs.[18] In Sri Lanka the most common radiological method used to investigate LBP is plain radiographs of the lumbar sacral spine. This is due to low cost and availability in most hospitals.[19] To date very little documented evidence is available with regard to radiological features associated with LBP in Asian countries. Therefore, this study was carried out to determine the association between chronic LBP and vertebral osteophytes, disc space narrowing, spondylolisthesis and vertebral fractures.

MATERIALS AND METHODS

This case control study was done in the two largest family medicine clinics in Ragama Sri Lanka from January 2012 to June 2013. Ragama is a suburb of the capital city of Colombo.

To determine the sample size, the prevalence of vertebral osteophytes in the spine was selected as a causative factor. According to a prevalence study 78% of people had vertebral osteophytes in their spines.[20] By using this data and an odds ratio (OR) of 3 and a power of 80 the sample size was calculated. A minimum sample size of 126 cases and 126 controls were required and selected from these clinics. Consecutive male and female persons aged 18 years and above with chronic LBP were selected as cases and without LBP were selected as controls. Pain that lasted for more than 3 months (continuous or intermittent pain) was considered as chronic pain.[21] The numerical rating scale (NRS) (e.g., 0 to 10-point scale. 0 equals no pain, 1–2 equals very mild pain, 3–4 equals mild pain, 5–6 equals moderate pain, 7–8 equals severe pain, 9–10 equals very severe pain) is an important uni-dimensional measure of pain which can be easily understood by many patients. The response to this scale can be used to determine the proportion of participants with pain, its intensity and the relationship between pain and other health-related conditions.[22] We used the NRS to measure the intensity of pain among the participants in our study.

Cases

The patients who had a pain NRS scale of more than 2 and had LBP that lasted for more than 3 months continuously or intermittently and who had radiographs of the lumbar sacral region were included as cases.

Exclusion criteria

The patients who had LBP due to systemic causes such as spinal tumors and infections or due to a direct significant blow to the spine were excluded. However, patients who developed LBP as a result of performing activities of daily living, occupation and recreation were included as cases.

Controls

Patients who did not have LBP but had other symptoms such as abdominal pain which necessitated them to have radiographs of the lumbar sacral region were included as controls.

Cases and controls were matched for age and sex. The cases were divided into 10-year age groups to enable frequency matching of controls on the basis of age.

The protocol for the research project was approved by a suitably constituted Ethics Committee of a Faculty of Medicine in the Colombo North region of Sri Lanka. The work was performed in accordance with the ethics standards laid down in an appropriate version of the Declaration of Helsinki (as revised in Brazil 2013). All persons gave their informed consent prior to their inclusion in the study.

A pre-tested structured interviewer-administered questionnaire was used to collect information about demographic data, data relating to physical activities done at home and at work and character of pain. The final questionnaire was prepared after two pretests. Weights and heights were measured to calculate the BMI using standard procedures.

Commonly used method to investigate patients with LBP is plain radiography of the spine.[23] Therefore, postero-anterior and lateral radiographs of the lumbar sacral spine of patients with chronic LBP and without back pain were selected for the study. The radiographs with technical errors such as poor penetration, and those not properly centered as determined by two independent radiologists were excluded. All radiographs were read by two radiologists working independently for the presence of osteophytes, disc space narrowing, spondylolisthesis and vertebral fractures.

Osteophytes were divided into three categories according to the presence or absence of osteophytes and according to the sizes of osteophytes as described by Hicks *et al.*[16]

Method used to detect disc space narrowing

The lateral radiographs were used for this purpose. A line was drawn along the inferior border of the vertebral body in an anterior posterior direction and extended posteriorly toward the facet joints[24] (Fig. 1).

If there is no disc space narrowing this line passes along or just over the superior margin of the facet joints. When there is a mild disc space narrowing this line passes below the superior margin of the facet joints. In severe disc space narrowing this line passes below the mid-height level of the facet joints.[25] These criteria were used to categorize disc space narrowing into three grades.[24]

Method used to detect spondylolisthesis

To detect spondylolisthesis lateral radiographs were used. Vertical lines were drawn along the anterior and posterior borders of the vertebral bodies (Fig. 2). These two lines were used to detect an anterior or a posterior shifting of a vertebra in relation to the other vertebrae.[25]

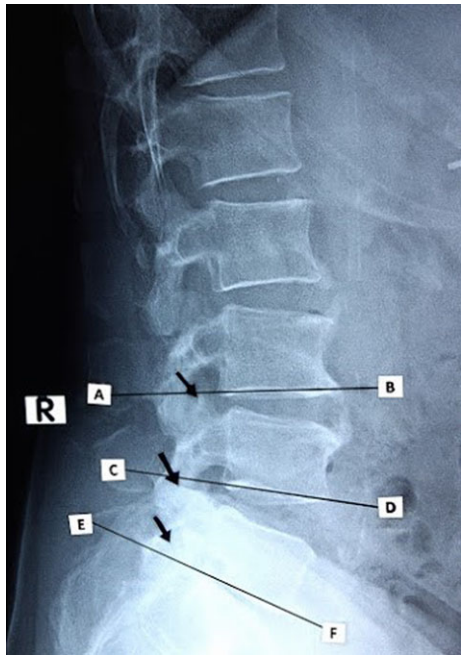

Figure 1 Lateral view X-ray of a lumbar sacral spine to detect intervertebral disc space narrowing. The AB and CD lines pass along the upper margins of the facet joints between the third and fourth and fourth and fifth lumbar vertebrae, respectively. EF line passes below the mid-level of the facet joint between the fifth lumbar and the first sacral vertebra. It indicates a severe intervertebral disc space narrowing between the fifth lumbar and the first sacral vertebrae.

Spondylolisthesis was defined as a forward slip or backward slip of one vertebral body by at least 5% in relation to the next most caudal vertebral body. According to the severity of the slip the spondylolisthesis was categorized into five grades.[25]

Method used to detect vertebral fractures

Lateral radiographs were used to detect vertebral fractures. Two points were marked at the highest points of the anterior end and the posterior end of the superior border of the vertebral body. From these two points direct vertical lines were drawn to the inferior border of the vertebral body and two points were marked in the inferior border[13] (Fig. 3).

These four points were used to measure the anterior and posterior vertebral heights with a Vernier caliper. A radiologist checked for the accuracy of these measurements.

Figure 2 Lateral view X-ray of a lumbar sacral spine to detect spondylolisthesis. Two vertical lines are drawn along the anterior and posterior borders of the vertebral bodies to detect a spondylolisthesis. There is no spondylolisthesis visible in this X-ray.

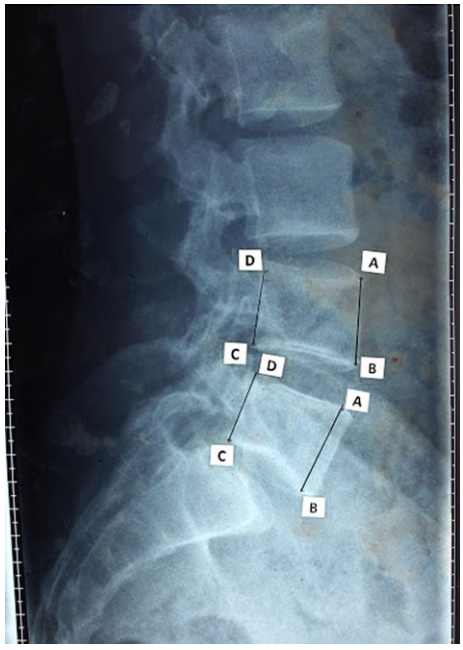

Figure 3 Lateral view X-ray of a lumbar sacral spine to measure the anterior and posterior heights of the fourth and fifth lumbar vertebral bodies. AB lines denote the anterior heights of the fourth and fifth vertebral bodies. CD lines denote the posterior heights of the fourth and fifth vertebral bodies.

To see whether the results were reproducible, repeat measurements were carried out on 10 radiographs. This showed that the individual measurements would be within $\pm$ 0.16 cm of the actual value at 95% significance.[26]

The antero-posterior ratio (A/P ratio) was calculated by dividing the anterior height of the vertebra by the posterior height of the same vertebra.

There are no calculated A/P ratio values for South Asian populations. Therefore, a value below 0.66 that was considered as having an osteoporotic vertebral fracture by Johansson *et al.* was used to detect vertebral fractures.[27] This value has been used to detect vertebral fractures of people who were above 85 years of age and in our population the mean age was 50 years.

Since we assumed that this value may not be an ideal value to detect vertebral fractures in our population, in addition to the value of 0.66 we used another A/P ratio value to detect vertebral fractures.

The mean A/P ratio value minus 1.64 SD in the control group was selected as the cutoff value to detect vertebral fractures. The A/P ratio values of less than mean minus 1.64 SD will classify about 5% of the controls as having an abnormal A/P ratio.[26] The new A/P ratio value calculated by this method was 0.89.

Bivariant analysis was done to find out the individual associations between vertebral fractures, disc space narrowing, spondylolisthesis and vertebral osteophytes with LBP. Multivariant analysis was done to find out the factors that had a significant association with LBP after adjusting for confounding effects. The data were analyzed using Stata 14 software.[28]

RESULTS

Radiographs of 140 cases and 140 controls were studied. Mean (SD) age for cases was 51.6 years (17). Mean (SD) age for controls was 50 years (15). There were 62% females among cases and controls.

Vertebral osteophytes and LBP

Vertebral osteophytes were present in 77% of cases and 67% of controls. This difference was statistically not significant (P = 0.102) (Table 1).

Disc space narrowing and LBP

Disc space narrowing was present in 15% of cases (mild disc space narrowing in 11% and severe disc space narrowing in 4%) and 6% of controls (mild disc space

Table 1 Results of bivariant analysis for association between low back pain and changes of the spine

Radiological change	Low backache				OR	χ^2	*P*-value
	Yes	%	No	%			
Osteophytes							
Grade 0	32	23	47	33	1.15	4.57	0.102
Grade 1	32	23	23	17			
Grade 2	76	54	70	50			
Total	140	100	140	100			
Disc space narrowing							
Grade 0	119	85	132	94	2.45	6.86	0.032
Grade1	16	11	7	5			
Grade 2	5	4	1	1			
Total	140	100	140	100			
Spondylolisthesis							
Grade 0	128	91	131	94	1.36	0.46	0.496
Grade 1	12	9	9	6			
Total	140	100	140	100			
L4 vertebral fracture (A/P ratio ≤ 0.89)							
Grade 0	87	62	125	89	5.07	28.05	< 0.001
Grade 1	53	38	15	11			
Total	140	100	140	100			
L5 vertebral fracture (A/P ratio ≤ 0.89)							
Grade 0	48	34	120	86	11.5	78.64	< 0.001
Grade 1	92	66	20	14			
Total	140	100	140	100			
L5 vertebral fracture (A/P ratio ≤ 0.66)							
Grade 0	138	99	139	99.3	2.0	0.33	0.566
Grade 1	2	1	1	0.7			
Total	140	100	140	100.0			

OR, odds ratio; A/P ratio, antero-posterior ratio; L4, fourth lumbar vertebra; L5, fifth lumbar vertebra.
Osteophytes: Grade 0 – no evidence of osteophytes, Grade 1 - presence of small (< 3 mm) osteophytes and Grade 2 – presence of small and large (≥ 3 mm) osteophytes.
Disc space narrowing: Grade 0 – no evidence of disc space narrowing, Grade 1 – presence of mild disc space narrowing and Grade 2 – presence of severe disc space narrowing.
Spondylolisthesis was graded in the following manner. Grade 0: no slip; Grade 1: ≥ 5% and < 25%; Grade 2: 26–50%; Grade 3: 51–75%; Grade 4: 76–100%; and Grade 5: complete slippage.

narrowing in 5% and severe disc space narrowing in 1%). This difference was statistically significant (OR = 2.45; $P = 0.032$) (Table 1).

Spondylolisthesis and LBP

Nine percent of cases and 6% of controls had spondylolisthesis. This difference was statistically not significant ($P = 0.496$) (Table 1). All the cases and controls only had mild (Grade 1) spondylolisthesis.

Vertebral fractures and LBP

When an A/P ratio value of 0.66 was used as the cutoff point to detect vertebral fractures, only 1% of cases and controls had a vertebral fracture in the fifth lumbar vertebra. This difference was statistically not significant ($P = 0.566$) (Table 1).

When an A/P ratio value of 0.89 was used as the cutoff point to detect vertebral fractures of the fourth lumbar vertebra, 38% of cases and 11% of controls had vertebral fractures. This difference was statistically significant (OR= 5.07; $P < 0.001$) (Table 1).

When an A/P ratio value of 0.89 was used as the cutoff point to detect vertebral fractures of the fifth lumbar vertebra, 66% of cases and 14% of controls had vertebral fractures. This difference was statistically significant (OR = 11.5; $P < 0.001$) (Table 1).

As most of the above causes (variables) are related and confound each other, the results of bivariant analysis may be misleading. To identify the predictor variables which had a significant association with LBP while controlling all other predictor variables, logistic regression analysis was undertaken. According to the

Table 2 Results of logistic regression for association between low back pain and changes of the spine

Variable	OR	*P*-value	95% CI for OR	
			Lower	Upper
Disc space narrowing				
Grade 0 (base)	1.00			
Grade 1	4.15	0.009	1.43	12.06
Grade 2	4.57	0.233	0.38	55.61
A/P ratio value of 0.89 for L4 vertebra				
Grade 0 (base)	1.00			
Grade 1	2.49	0.017	1.18	5.28
A/P ratio value of 0.89 for L5 vertebra				
Grade 0 (base)	1.00			
Grade 1	10.20	< 0.001	5.47	19.01

OR, odds ratio; CI, confidence Interval; A/P ratio, antero-posterior ratio.
Disc space narrowing - Grade 0 – no evidence of disc space narrowing, Grade 1 – presence of mild disc space narrowing and Grade 2 – presence of severe disc space narrowing.

results of logistic regression after adjustments for confounding effects, only disc space narrowing ($P = 0.009$) and vertebral fractures of fourth ($P = 0.017$) and fifth ($P \leq 0.001$) lumbar vertebrae had significant associations with LBP (Table 2).

DISCUSSION

Vertebral osteophytes, disc space narrowing, vertebral fractures and spondylolisthesis were present in patients with LBP and in people without LBP.

Disc space narrowing

In the present study disc space narrowing had a significant association with LBP. According to the study findings of Iwamoto *et al.* on high-school rugby players, the people with disc space narrowing have a greater chance of developing low backache compared to people with no radiological changes of the spine.[29] A study done among young military recruits by Mattila *et al.* has shown that 29% of the causes for LBP are due to lumbar disc disorders.[30] Our study findings agree with the above study findings of Iwamoto *et al.*[30] and Mattila *et al.*[31]

According to a community-based study (mean age of > 65 years) prevalence of disc space narrowing has been estimated to be 50–64%.[14] In the present study the mean age of cases was 51.6 years. The prevalence of disc space narrowing in the present study is less than the findings of the above study. Differences in the age limit of the two study populations may be a contributory factor for this difference. Disc space narrowing occurs due to disc herniations. Centro-lateral herniations have been associated with dermatomal distribution of pain due to impingement on spinal nerves[31] and central herniations have been associated with severe back pain.[32] Prostaglandin E2 plays an important role in the radiculopathy of lumbar disc herniation. The cytoplasm of chondrocytes contains the enzyme cyclooxygenace-2 (COX-2), which is necessary to synthesize prostaglandin E2 responsible for the inflammation, which occurs during, damaged to the disc.[33] These may be some of the reasons why disc space narrowing is an important cause for LBP in the present study. According to the present study findings people with severe disc space narrowing (OR = 4.57; $P = 0.233$) had a higher chance of developing LBP compared to people with mild disc space narrowing (OR –4.15, $P = 0.009$) (Table 2). However, severe disc space narrowing failed to reach the significant level since only a small number of cases and controls had severe disc space narrowing.

Vertebral osteophytes

In our study vertebral osteophytes did not show a significant association with LBP. A descriptive cross-sectional study demonstrates that 73.6% of adult patients with LBP had osteophytes and the commonest site of osteophytes was the anterior margin of the vertebral body.[4] They also demonstrated that the chance of developing vertebral osteophytes is greater with increasing age. A retrospective small longitudinal study done among Japanese male self-defense forces also found a significant association between LBP and vertebral osteophytes.[5] Vertebral osteophytes growing from the posterior edge of the vertebrae can cause narrowing of the vertebral canal and also impinge on nerve roots and cause LBP and leg pain, but osteophytes occurring in the anterior region of the vertebrae and small osteophytes in the posterior region of vertebrae do not compress the vertebral canal and impinge on nerve roots.[16] In the present study, cases and controls were in the similar age range and both groups had a high prevalence of osteophytes. Similar age ranges may have contributed to both groups having a similar prevalence of osteophytes in our study. In the present study most of the osteophytes among cases and controls were found in the anterior region. Therefore, this could be another reason why in the present study osteophytes did not have a significant association with LBP. Most studies that have found a significant association between osteophytes and LBP are descriptive cross-sectional studies.

Prevalence of osteophytes and LBP both increase with age. Therefore, to identify osteophytes as a significant cause for LBP cases needs to be compared with an age- and sex-matched control group. Case control studies done to find the prevalence of osteophytes among people with back pain and without back pain are very scarce.

Spondylolisthesis

According to our study findings spondylolisthesis did not have a significant association with LBP. Spondylolisthesisis is common among middle-aged and elderly adults in the United States and the prevalence is in the range of 14–30%.[34] A descriptive cross-sectional study done among elderly Chinese men and women demonstrated that the prevalence among men and women is 19.1% and 25%, respectively and spondylolisthesis can cause LBP, numbness and weakness in the legs or lower extremities.[26] Prevalence of spondylolisthesis in our study is less than the prevalence of spondylolisthesis of the two above studies. Age-associated degeneration of the spine contributes to the development of spondylolisthesis.[4] In the present study both cases and controls were in the similar age range and this could be a contributory factor for both the cases and controls having a similar prevalence of spondylolisthesis. Studies that have found a significant association between spondylolisthesis and LBP are descriptive cross-sectional studies. Without comparing with an age-matched control group, it is not possible to identify spondylolisthesis as a significant cause for LBP. Case-control studies done to compare the prevalence of spondylolisthesis among people with back pain and without back pain are very limited in number.

Vertebral factures

When an A/P ratio value of equal to or less than 0.66 was used as a cutoff point to detect vertebral fractures, our study could not find a significant association between vertebral fractures and LBP. Johansson *et al.* used this A/P ratio value to detect vertebral fractures on a sample of people aged 85 years or more.[27] In the present study the mean age of cases and controls was 51.6 years and 50 years, respectively. Therefore, a cutoff value of 0.66 may not be suitable to detect vertebral fractures in the present study sample.

Since there are no accepted A/P ratio values for Sri Lankans and other countries in the region, the new calculated A/P ratio value of 0.89 was used as the cutoff point to detect fractures of the fourth and fifth lumbar vertebrae. When this A/P ratio value was used, vertebral fractures of fourth and fifth lumbar vertebrae had a significant association with LBP. There are no prevalence studies done with regard to osteoporotic vertebral fractures in Sri Lanka.

A person with an A/P ratio value of less than 0.89 for fifth and fourth lumbar vertebrae had, respectively, 10 times and three times greater chance of having LBP compared to a person who has an A/P ratio value of more than 0.89. According to a study done on children between the ages 3–17 years found that an A/P ratio of less than 0.89 for vertebrae from the 10th thoracic to third lumbar vertebrae raises the possibility of vertebral injury and the A/P ratio did not have a significant association with age.[35] Their study does not mention any A/P ratio value for fourth and fifth lumbar vertebrae. Our study A/P ratio value for fourth and fifth lumbar vertebrae was similar to the above study. Therefore, the A/P ratio value (0.89) detected in our study may be useful in detecting vertebral injury among fourth and fifth lumbar vertebrae of children. The present study is one of the very few studies that have found an A/P ratio value for fourth and fifth lumbar vertebrae that has a significant association with LBP. However, as this cutoff was derived at by using the current data set, it is not possible to validate it using the current data set. In order to validate this, cutoff value as a predictor of vertebral fracture, the performance of the recommended cutoff value for A/P ratio should be compared using it on a different data set.

According to the findings of this study, out of the radiological changes of the spine, only disc space narrowing and vertebral fractures had a significant association with LBP and the vertebral fracture of the fifth lumbar vertebra had the highest association with LBP. The cutoff value used to detect vertebral fractures in this study will help in the early detection of vertebral fractures. The result of the present study will be useful to clinicians and scientists to provide advice to patients presenting with LBP, make decisions with regard to management and conduct further research related to LBP.

AUTHOR CONTRIBUTIONS

ALK was involved in conception and designing the study, patient management, data collection, statistical analysis and interpretation of data, drafting the manuscript and revising it critically. AP was involved in statistical analysis, interpretation of data and critically reviewing the manuscript. LSW was involved in patient management and designing the study. All three authors read and approved the final manuscript.

ACKNOWLEDGEMENTS

We are grateful to the National Research Council for providing funds (NRC grant 99) to conduct this study and the Sri Lanka Higher Education Ministry for providing a research allowance to conduct research.

REFERENCES

1 Nisha JM, MacGregorb AJ (2005) Epidemiology of back disorders, prevalence, risk factors and prognosis. *Curr Opin Rheumatol* **17**, 134–40.
2 Goode AP, Carey TS, Jordan JM (2013) Low back pain and lumbar spine osteoarthritis: how are they related? *Curr Rheumatol Rep* **15**, 305.
3 Gellhorn AC, Chan L, Martin B, Friedly J (2012) Management patterns in acute low back pain: the role of physical therapy. *Spine (Phila Pa 1976)* **37**, 775–82.
4 Igbinedion BOE, Akhigbe A (2011) Correlations of radiographic findings in patients with low back pain. *Niger Med J* **52**, 28–34.
5 Nemoto O, Kitada A, Naitou S, Tsuda Y, Matsukawa K, Ukegawa Y (2013) A longitudinal study for incidence of low back pain and radiological changes of lumbar spine in asymptomatic Japanese military young adults. *Eur Spine J* **22**, 453–8.
6 Deyo RA, Weinstein JN (2001) Low back pain. *N Engl J Med* **344**, 363–70.
7 Javinen TLN, Michaelsson K, Aspenberg P, Sivanen H (2015) Osteoporosis: the emperor has no clothes. *J Intern Med* **277**, 662–73.
8 Panda A, Das CJ, Baruah U (2014) Imaging of vertebral fractures. *Indian J Endocrinol Metab* **18**, 295–303.
9 Kitahara H, Aoyagi Z, Ye K *et al.* (2013) Associations of vertebral deformities and osteoarthritis with back pain among Japanese women: the Hizen-Oshima study. *Osteoporos Int* **24**, 907–15.
10 Waterloo S, Søgaard AJ, Ahmed LA, Damsgård E, Morseth B, Emaus N (2013) Vertebral fractures and self-perceived health in elderly women and men in a population-based cross-sectional study: the Tromsø Study 2007–08. *BMC Geriatr* **13**, 102.
11 Nuti R, Caffarelli C, Guglielmi G, Gennari L, Gonnelli S (2014) Undiagnosed vertebral fractures influence quality of life in postmenopausal women with reduced ultrasound parameters. *Clin Orthop Relat Res* **472**, 2254–61.
12 Diacinti D, Pisani D, Barone-Adesi F *et al.* (2010) A new predictive index for vertebral fractures: the sum of the anterior vertebral body heights. *Bone* **46**, 768–73.
13 Tatori G, Rokita E, Wiobei A (2013) Application of geometrical measurements in the assessment of vertebral strength. *Pol J Radiol* **78**, 15–8.
14 Quint U, Hans-Joachim Wilke HJ (2008) Grading of degenerative disk disease and functional impairment: imaging versus patho-anatomical findings. *Eur Spine J* **17**, 1705–13.
15 Mulholland RC (2008) The myth of lumbar instability: the importance of abnormal loading as a cause of low back pain. *Eur Spine J* **17**, 619–25.
16 Hicks GE, Morone N, Weiner DK (2009) Degenerative lumbar disc and facet disease in older adults. Prevalence and clinical correlates. *Spine (Phila Pa 1976)* **34**, 1301–6.
17 Lee H, Seo JC, Kwak M *et al.* (2014) Acupuncture for low back pain due to spondylolisthesis: study protocol for a randomized controlled pilot trial. *Trials* **5**, 105.
18 Kalichman L, Kim D, Li L, Guermazi A, Hunter DJ (2010) Computed tomography–evaluated features of spinal degeneration: prevalence, intercorrelation, and association with self-reported low back pain. *Spine J* **3**, 200–8.
19 Karunanayake A, Pathmeswaran A, Wijayaratne LS (2007) Radiological changes of the spine in patients with chronic low backache. *Med Today* **5**, 6–9.
20 O'Neill TW, McCloskey EV, Kanis JA *et al.* (1999) The distribution, determinants and clinical correlates of vertebral osteophytosis: a population based survey. *J Rheumatol* **26**, 842–8.
21 Treede RD, Rief W, Barke A *et al.* (2015) Classification of chronic pain for *ICD-11*. *Pain* **156**, 1003–7.
22 Shega JW, Tiedt AD, Grant K, Dale W (2014) Pain measurement in the national social life, health, and aging project: presence, intensity, and location. *J Gerontol B Psychol Sci Soc Sci* **69**, S191–7.
23 Wilmink JT (2010). *Lumbar Spinal Imaging in Radicular Pain and Related Conditions. Understanding Diagnostic Images in a Clinical Context*. Springer Verlag, Berlin.
24 Macnab I (1978). *Macnab's Backache*. Williams and Wilkins, Baltimore, USA.
25 He LC, Wang YX, Gong JS *et al.* (2014) Prevalence and risk factors of lumbar spondylolisthesis in elderly Chinese men and women. *Eur Radiol* **24**, 441–8.
26 Bland M (2003). *An Introduction to Medical Statistics*. Oxford University Press, New York.
27 Johanson C, Mellstrom D, Rosengren K, Rudigren A (1994) A community based population study of vertebral fractures in 85 year old men and women. *Age Ageing* **23**, 388–92.
28 StataCorp (2015). *Stata Statistical Software: Release 14*. StataCorp LP, College Station, TX.
29 Iwamoto J, Abe H, Tsukimura Y, Wakani K (2015) Relationship between radiographic abnormalities of lumbar spine and incidence of low back pain in high school rugby players; a prospective study. *Scand J Med Sci Sports* **15**, 16.
30 Mattila VMP, Visuri ST, Pihlajamäki H (2009) Incidence and trends of low back pain hospitalization during military service -An analysis of 387,070 Finnish young males. *BMC Musculoskelet Disord* **10**, 10.
31 Janardhana AP, Rao RS, Kamath A (2010) Correlation between clinical features and magnetic resonance imaging

findings in lumbar disc prolapsed. *Indian J Orthop* **44**, 263–9.

32 Pearson AM, Blood EA, Frymoyer JW *et al.* (2008) Lumbar intervertebral disk herniation and back pain. Does treatment, location, or morphology matter?. *Spine (Phila Pa 1976)* **33**, 428–35.

33 Miyamoto H, Saura R, Harada T, Doita M, Mizuno K (2000) The role of cyclooxygenace-2 and inflammatory cytokines in pain induction of herniated lumbar intervertebral disc. *Kobe J Med Sci* **46**, 13–28.

34 Denard PJ, Holton KF, Jessica M *et al.* (2010) Back pain, neurogenic symptoms, and physical function in relation to spondylolisthesis among elderly men. *Spine J* **10**, 865–73.

35 MariaGaca A, Barnhatt HX, Bigget GS (2010) Vertebral body Antero posterior ratio. *Paediatr Imag* **194**, 516–20.