Lumbar Segmental Motion: A Correlation of Clinical Symptoms with MRI and Dynamic Radiograph

Dr Esmat SM[1], Dr Wan Zainuddin WAR[2], Dr Tiw ZS[3], Dr Razip S[4], Dr Laili SAL[5], Rohidayah AM[6]

[1]Orthopedic Department, Hospital Pakar Sultanah Fatimah, Johor, Malaysia (Corresponding Author)
[2]Orthopedic Department, Hospital Kuala Lumpur, Malaysia
[3, 4]Orthopedic Department, Hospital Pakar Sultanah Fatimah, Johor, Malaysia
[5]Radiology Department, Hospital Pakar Sultanah Fatimah, Johor, Malaysia
[6]Clinical Research Center, Hospital Pakar Sultanah Fatimah, Johor, Malaysia

Abstract: ***Background**: Dynamic radiograph is commonly proposed to diagnose lumbar instability but no study was performed to prove the correlation with both symptoms and MRI findings. **Objectives**: The purpose of this study is to determine the correlation between lumbar segmental motion and MRI with clinical symptoms at the level of L4/L5 and L5/S1. **Methods**: A cross sectional study of 50 patients with back pain who have done MRI lumbosacral was performed between 1st April 2019 to 31st October 2019. Lumbosacral dynamic x-ray, assessment for visual analogue pain scale (VAS) and modified Oswestry disability index (ODI) were done during outpatient visit. Degree of disc degeneration (DD), facet joint osteoarthritis (FJO), and ligamentum flavum hypertrophy (LFH) were determined from MRI lumbosacral whilst the segmental motions were manually measured from dynamic x-rays. Horizontal motion ≥ 4 mm and angular motion of >20^0 at L4/L5 and >25^0 at L5/S1 are considered excessive. **Results**: The overall incidence of excessive horizontal motion was 10% at L4/L5 and 12% at L5/S1 while excessive angular motion was 14% at both L4/L5 and L5/S1. At L4/L5, it was noted that FJO grade III and angular motion both had significant correlation to predict worsening VAS with p-value of 0.033 and 0.037, respectively. At L5/S1 level, only horizontal lumbar motion was found to have a statistically significant correlation to predict higher ODI score with p-value of 0.001. **Conclusions**: Comprehensive assessment both clinically and radiologically is paramount in determining the appropriate diagnosis and management of lumbar instability.***

Keywords: lumbar vertebrae, segmental motion, instability, disc degeneration, facet joint osteoarthritis, ligamentum flavum hypertrophy

1. Introduction

Back pain is becoming more prevalent as the population reaches longer life expectancy. With severity ranging from mild nuisance to crippling disability, interests in the best diagnostic method to determine the etiology of back pain remain high. One of the etiologies associated with back pain is believed to be lumbar instability[1]. The diagnosis of lumbar instability as the cause of back pain remains a challenging affair. This in part may be contributed by the dynamic nature of the condition that is associated with excessive motion of the lumbar segments.

Dynamic radiography in flexion and extension is widely used as primary method to diagnose excessive lumbar motion due to its simplicity and cost effectiveness. However, this method is still debatable due to lack of reproducibility, non standardized method of performing the x-ray, and inconsistent measurement method[2].

MRI is considered to be the best method to study lumbar spines as it can elicit most pathologies like stenosis, facet joint osteoarthritis (FJO), ligamentum flavum hypertrophy (LFH), and degenerative discs (DD). Some of the findings like FJO and LFH have been found to have significant correlation with lumbar instability[3]. However, as it often done in static supine position, any motion pathology may be missed. Although multiple studies have been done on lumbar segmental motions, none has found a strong and consistent correlation linking severity of symptoms to the radiologic findings. Furthermore, no studies have been done to determine the relationship between the severity of symptoms to both MRI and dynamic radiography.

This study aims to determine whether severity of back pain caused by excessive motion of lumbar segment can be predicted by the severity of dynamic radiograph and MRI findings. By establishing the correlation, one would be able to predict the severity of back pain due to instability by first analyzing dynamic radiography. With better understanding regarding the correlation of symptoms and radiographic findings, better treatment appropriate to the condition of the patients can be applied thus increasing satisfaction and quality of life.

2. Materials and Methods

A total of 50 subjects was enrolled in this cross-sectional study from 1st April 2019 to 31st October 2019. Inclusion criteria for the study includes all patients aged 18 and above who presented with lower back pain and have undergone MRI lumbosacral. Exclusion criteria include patients with previous history of spinal trauma, spine surgery, vertebral infection, congenital spine deformity as well as pregnancy and paediatric patients.

Upon visit in clinic, dynamic radiograph in flexion and extension position was performed and the clinical symptoms assessed with VAS and revised ODI scores.

ODI score is a set of questionnaires containing 10 questions to measure functional disability caused by back pain. The score is interpreted in percentage form into 5 level of disability including minimal disability (0%-20%), moderate disability (21%-40%), severe disability (41%-60%), crippled (61%-80%), and bed bound (81%-100%)[4]. The questionnaires were answered by subjects during the outpatient visit.

VAS score is a standardized tool utilized to measure pain intensity. Subjects were instructed to choose from a scale of one till ten with higher score signifying worse pain[5].

Dynamic radiography of lumbosacral in flexion and extension position were done during the same visit. Both x-rays were taken in standing position from lateral view. The distance between the film and radiographic tube was 150cm. The pelvis was stabilized with an adjustable stabilizing rod to prevent flexion and extension of the hip joint. For the flexion radiograph, patients were asked to bend forward as much as possible followed by further flexion force applied by the examiner until they reported discomfort (**Figure 1**). In extension position, the extension force was applied over the shoulder instead (**Figure 2**). Both radiographs were taken in each position of maximum flexion and extension[6].

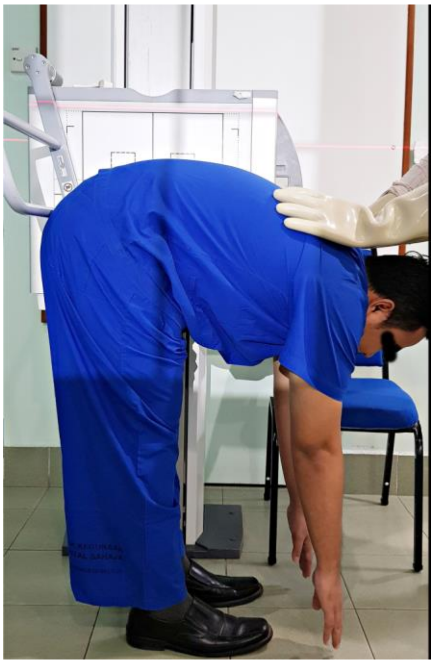

Figure 1 : Dynamic radiograph in hyperflexion.

Figure 2 : Dynamic radiograph in hyperextension

Lumbar horizontal and angular motion in each segment were measured using the method described by White and Panjabi[7]. Horizontal motion is measured with two lines that were drawn perpendicular to posterior edges of superior and inferior endplates. The distance between the lines was measured. Horizontal motion was the difference between the 2 distances in flexion and extension. 4mm or more translation was considered excessive motion. The angular motion was measured as the difference of intervertebral angles in both flexion and extension radiographs. Difference of more than 20° at L4/L5 or more than 25° at L5/S1 was considered unstable.

MRI lumbosacral was done in supine position with Phillips Achievable 1.5 Tesla System. The studies consisted of four spin-echo sequences with repetition time and echo time (TR/TE) of 328ms/120ms. Images were analysed and reported by 1 radiologist. MRI findings were extracted retrospectively as only subjects who have done MRI will be selected in this study to compare the result with dynamic radiography and clinical symptoms.

Three main parameters reported were grade of disc degeneration (DD), severity of facet joint osteoarthritis (FJO), and presence of ligamentum flavum hypertrophy (LFH). Disc degeneration was classified into five grades based on Pfirrmann's criteria[8]. Grade I was considered normal discs and Grade V corresponded to advanced degeneration. FJO was classified into 4 grades according to Fujiwara's method[9]. Grade 1 was normal facet joints while grade 2, 3, 4 corresponded to mild, moderate, and severe facet joints degeneration, respectively. LFH was classified as being either negative or positive depending on its presence in each lumbar segment.

This study has been approved by Medical Research and Ethics Committee and informed consent were taken from patients before they were included in the study.

Descriptive statistics of percentage, mean and standard deviation were utilized to summarize data. The associations between demographic characteristics with segmental motion and MRI findings were studied using Chi-square, independent t-test and one-way ANOVA. Association of MRI parameters (DD, FJO and LFH) and lumbar segmental motions (horizontal and angular) with ODI at L4/L5 and L5/S1 were analysed using multiple linear regression. Additionally, association of MRI parameters (DD, FJO, LFH) and lumbar segmental motions (horizontal and angular) with VAS at L4/L5 and L5/S1 were investigated using ordinal logistic regression. The significance level was set at a p-value of < 0.05. All statistical analyses were performed using SPSS version 22.0.

3. Results

The overall incidence of excessive horizontal motion is 10% at L4/L5 and 12% at L5/S1 while excessive angular motion is 14% at L4/L5 and 14% at L5/S1.

Table 1: Demographic data

Data		**n**	**Percentage (%)**
Age		44.84, 13.56(Mean, SD)	
Gender	Male	24	48
	Female	26	52
BMI		27.53, 4.94 (Mean, SD)	
Occupation	White Collar	20	40
	Blue Collar	30	60

A total of 50 subjects of 24 males and 26 females are studied with the mean age of 44.84 ± 13.56. Demographic data is summarized in **Table 1**.

Table 2: Association between demographic characteristic and lumbar segmental motion

Demographic Characteristic	**Spinal Level**		**Horizontal Motion**		***p*-value**	**Angular Motion**		***p*-value**
			<4mm	≥4mm		Stable	Unstable	
AGE	L4/L5	n (%) mean, SD	45(90.0) 44.5,13.0	5 (10.0) 48.2,19.8	0.565**	43(86.0) 43.5,13.3	7(14.0) 53.3,13.0	0.075**
	L5/S1	n (%) mean, SD	44(88.0) 43.6,13.4	6 (12.0) 53.7,12.4	0.089**	43(86.0) 43.7,13.4	7(14.0) 52.0,13.4	0.133**
GENDER	L4/L5	MALE FEMALE	21 (42.0) 24 (48.0)	3 (6.0) 2 (4.0)	0.571*	19 (38.0) 24 (48.0	5 (10.0) 2 (4.0)	0.181*
	L5/S1	MALE FEMALE	19 (38.0) 25 (50.0)	5 (10.0) 1 (2.0)	0.065*	20 (40.0) 23 (46.0)	4 (8.0) 3 (6.0)	0.602*
BMI	L4/L5	n (%) mean, SD	45 (90.0) 27.9,4.8	5 (10.0) 24.4,5.5	0.142**	43(86.0) 27.8,5.0	7(14.0) 26.0,4.5	0.374**
	L5/S1	n (%) mean, SD	44 (88.0) 27.6,4.9	6 (12.0) 26.7,5.9	0.670**	43(86.0) 27.9,5.0	7(14.0) 25.1,4.1	0.166**
OCCUPATION	L4/L5	White Collar Blue Collar	18 (36.0) 27 (54.0)	2 (4.0) 3 (6.0)	1.00*	15 (30.0) 28 (56.0)	5 (10.0) 2 (4.0)	0.067*
	L5/S1	White Collar Blue Collar	19 (38.0) 25 (50.0)	1 (2.0) 5 (10.0)	0.214*	19 (38.0) 25 (50.0)	1 (2.0) 5 (10.0)	0.214*

** χ2 test , ** Independent t-test*

When examined by lumbar level, no significant correlation is observed when comparing demographic characteristics (age, gender, BMI, and occupation) with lumbar motions as presented in **Table 2**. However, it is worthy to be noted that majority of excessive motion is observed in subjects with normal BMI.

Table 3: Association between age and MRI findings (DD, FJO, LFH)

Demographic Characteristic	Spinal Level		DD					p-Value
			Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	
Age	L4/L5	n (%) mean, SD	1 (2) 33.0, -	7 (14) 32.7, 6.2	16 (32) 40.1, 11.0	23 (46) 52.0,13.5	3 (6) 48.0, 11.1	0.002§
	L5/S1	n (%) mean, SD	2 (4) 31.0, 2.8	4 (8) 34.5, 7.7	14 (28) 43.0, 11.6	26 (52) 47.2,14.4	4 (8) 53.0, 14.3	0.136§
	Spinal Level		FJO					p-Value
			Grade 1		Grade 2	Grade 3	Grade 4	
	L4/L5	n (%) mean, SD	2 (4) 31.0,2.8		23 (46) 38.7,10.4	17 (34) 50.1,13.5	8 (16) 55.0,12.8	0.001§
	L5/S1	n (%) mean, SD	2 (4) 31.0,2.8		20 (40) 40.8,11.3	20 (40) 46.0,14.3	8 (16) 55.6,12.1	0.023§
	Spinal Level		LFH					p-Value
			Present			Absent		
	L4/L5	n (%) mean, SD	21 (42) 50.0,12.8			29 (58) 41.1,13.1		0.020**
	L5/S1	n (%) mean, SD	14 (28) 55.1, 14.6			36 (72) 40.8, 10.9		<0.001**

*** Independent t-test, § One-way ANOVA*

As displayed in **Table 3**, there is significant correlation between age and MRI findings (p-Value < 0.05) at both spinal level for FJO and LFH and at L4/L5 for DD. No significant correlation was detected when comparing MRI findings with other demographic characteristics (gender, BMI, and occupation).

Table 4: Multiple linear regression of MRI parameters (DD, FJO and LFH) and lumbar segmental motions (horizontal and angular) in predicting ODI at L5/S1

Parameters		β (95% CI)	t-stat	*p*-value
MRI	DD	-3.026 (-7.971,1.920)	-1.233	0.224
	FJO	1.489 (-4.046,7.023)	0.542	0.591
	LFH	-3.422 (-12.017,5.172)	-0.802	0.427
Dynamic radiograph	Horizontal Motion	5.884 (2.452, 9.317)	3.455	0.001
	Angular Motion	-0.591 (-1.408,0.226)	-1.457	0.152

Multiple linear regression of MRI parameters (DD, FJO and LFH) and lumbar segmental motions (horizontal and angular) in predicting ODI at L4/L5 did not produce a model of good fit for the data with F (5, 44) = 1.233, p=0.310, R^2=0.123. All of MRI parameters and lumbar segmental motions in the model did not show statistically significant correlation in predicting the severity of ODI at L4/L5. At L5/S1, the regression model produced a model of good fit for the data with F(5, 44) = 2.700, p= 0.033, R^2=0.235. However, there was only one significant linear relationship observed which was between horizontal lumbar segmental motion with ODI (p=0.001) as shown in **Table 4**. The linear relationship predicted that patient with 1mm more in horizontal lumbar segmental motion at L5/S1 will have ODI higher by 5.89% (95% CI: 2.45, 9.32). There were no other significant linear relationship of angular motion and all MRI parameters in predicting ODI at L5/S1.

Table 5: Multivariable ordinal logistic regression for the association of MRI parameters and lumbar segmental motion with VAS at L4/L5 and L5/S1

Independent Variables			B coefficient	OR	95% CI	*p*-value
L4/L5						
MRI Parameters	DD	Grade 1	38.689	6.345×10^{16}	6.345×10^{16},6.345×10^{16}	-
		Grade 2	-2.532	0.079	0.001,4.811	0.226
		Grade 3	-1.737	0.176	0.004,7.228	0.360
		Grade 4	-2.156	0.116	0.003, 4.302	0.242
		Grade 5	Reference			
	FJO	Grade I	-20.930	8.13×10^{-10}	-	0.998
		Grade 2	-0.270	0.763	0.083,7.015	0.812
		Grade 3	-2.499	0.082	0.008, 0.820	0.033
		Grade 4	Reference			
	LFH	Present	-0.008	0.992	0.274, 3.593	0.990
		Absent	Reference			
Dynamic Radiograph	Lumbar segmental motion	Horizontal (mm)	0.284	1.328	0.751,2.349	0.328
		Angular (Degree)	0.158	1.171	1.010, 1.359	0.037
L5/S1						
MRI Parameters	DD	Grade1	-0.729	0.482	0.013, 17.427	0.690
		Grade 2	-1.619	0.198	0.005, 7.675	0.386
		Grade 3	-2.242	0.106	0.005, 2.482	0.163
		Grade4	-2.051	0.129	0.007, 2.450	0.173
		Grade 5	Reference			
	FJO	Grade I	0a	-	-	-
		Grade 2	1.276	3.582	0.391, 32.819	0.259
		Grade 3	0.944	2.570	0.289, 22.851	0.397
		Grade 4	Reference			
	LFH	Present	0.194	1.214	0.325, 4.536	0.773
		Absent	Reference			
Dynamic Radiograph	Lumbar segmental motion	Horizontal (mm)	0.492	1.636	0.999, 2.680	0.051
		Angular (degree)	0.708	2.030	0.331, 1.466	0.444

At L4/L5, MRI parameter FJO Grade 3 as compared to grade 4 showed a significant association with negative coefficient to predict patient's VAS (OR=0.082; 95% CI, 0.008-0.820; p=0.033) after controlling DD, LFH and lumbar segmental motions. This indicates that patients with FJO Grade 3 are 0.08 times less likely than patient with FJO Grade 4 to have more severe VAS. Angular lumbar segmental motion also showed a significant association with positive coefficient to be a predictor for VAS (OR=1.171; 95% CI, 1.010-1.359; p=0.037) after controlling for horizontal motions and all MRI parameters. This implies that a patient with 1 degree increase in angular motion is 1.17 times more likely to have more severe VAS. Nonetheless, the association of DD, LFH and horizontal lumbar segmental motion were not significant after controlling the other independent variables as noted in **Table 5**. At L5/S1, all independent variables were non-significant to be a predictor for patient's VAS with all p-values more than 0.05.

4. Discussion

The lack of consensus in regard to the definition of lumbar instability remains a major issue in scientific investigation of lumbar spine instability. Widely accepted definition by Stokes and Frymoyer[10] described segmental instability as loss of motion segmental stiffness in such a way that force application to the motion segment produces greater displacement than is seen in a normal structure. In other words, the abnormal response to loads indicated mechanically by abnormal segmental motion can be defined as lumbar instability. White and Panjabi[11] define instability as the inability of the spine under physiologic loads to maintain relationships between vertebrae in such a way that there is neither initial damage nor subsequent irritation to the spinal cord or nerve roots and, in addition, there is no development of incapacitating deformity or pain due to the structural changes. In essence, the more comprehensive definition by White and Panjabi explains the possible relationship of back pain to segmental instability.

Functionally, Kirkaldy-Willis and Farfan[12] hypothesized three phases of lumbar degenerative disease in relation to instability. The three phases described are temporary dysfunction (phase I), unstable phase (phase 2), and stable phase (phase 3). The duration of each phase is variable with no definite symptoms or clinical signs differentiating them. This is proved in our study as severe lumbar degenerative changes seen in MRI do not necessarily cause more severe pain or instability.

Multiple studies have reported the correlation of lumbar DD with excessive lumbar segmental motion[1,13]. Murata, however, reported insignificant correlation between different grades of disc degeneration and lumbar segmental motion at the level of L4/L5 and L5/S1[14]. It is believed that the abnormal movements associated with lumbar DD can either be in quantity (excessive motion) or quality (anomalous coupling)[13]. Nonetheless, no significant correlation was found in our study.

The facet joints are one of the main factors that play a vital role in maintaining the stability of lumbar segments. Some changes in FJO include osteophyte formation, subchondral sclerosis and inflammation that effectively cause hypermobility of the facet joints[15]. This in turn may cause symptomatic back pain in the spinal level affected. Jang et al revealed in his study that at the level L4/L5, FJO were significantly associated with segmental instability[3].

Ligamentum flavum underwent increased thickness with aging evidenced by increasing fibrosis and reducing elastic fibers content[16]. In a prospective study involving the L4/L5 segment of 296 patients, Yoshiiwa stated that the development of LFH is closely related to segmental instability combined with disc degeneration[17]. Jang et al postulated that presence of LFH at level L3/L4 and L4/L5 were significantly associated with radiographic lumbar segmental instability[3]. On the contrary, we found no significant relationship between LFH with lumbar motions.

Lumbar segmental instability is one of the major causes of back pain and usually assessed preoperatively to decide on spinal fusion surgery. However, as reported by Weiler et al, lower back pain itself has a low specificity in diagnosing lumbar instability[18]. Iguchi et al concluded that patients with ≥3mm translation and $\geq 10^0$ angulation simultaneously showed significantly severe symptoms when compared to either radiographic finding separately[19]. In the present study, it was established that horizontal motion was found to be a significant predictor of ODI at L5/S1 with p- value of 0.033 whereas angular motion was noted to be a significant predictor of VAS at L4/L5 with p-value of 0.037.

A study of L4/L5 and L5/S1 segments on 591 patients revealed a strong correlation of severity of lumbar DD with increased ODI[20]. Middendorp et al concluded that severity of lumbar DD assessed using MRI is a strong indicator of severity of back pain. In other study, Maataoui et al found no significant correlation when comparing FJO with severity of clinical symptoms assessed with ODI scores[21]. In our study, it was determined that patients with FJO Grade 3 are less likely to have worse VAS score when compared to patients with FJO grade 4.

5. Conclusion

Direct relationships between lumbar segmental motion and MRI findings with clinical symptoms are still disputed. We conclude that increasing horizontal lumbar segmental motion is associated with higher ODI score while increasing angular motion along with higher FJO grades correlate with more severe VAS. Nevertheless, it is still worth to note that the etiology of back pain associated with instability may include more than one pathology. Thus, it makes perfect sense to assess all patients using both clinical and radiological methods available to confirm the diagnosis of lumbar instability before resolving on the next step of management.

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