RESEARCH ARTICLE

# Radiographic Investigation of Lumbar Vertebrae in Patients with Flexion and Extension Movement Disorder Syndrome

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## Abstract

**Objectives:** The kinesiopathology model is a new rehabilitation model classifying, evaluating, and treating patients with non-specific back pain. Sahrmann proposed this model based on movement disorder syndromes. The present cross-sectional study aimed to evaluate the radiograph of the linear and angular displacement of the lumbar spine in patients with lumbar flexion impairment syndrome (LFIS) and lumbar extension impairment syndrome (LEIS).

**Methods:** In this study, 50 adults aged 18-46 years were enrolled, including 25 patients with LFIS and 25 with LEIS. The eligible participants were referred to the radiology department for radiography in the common position of neutral, full extension, and full flexion position while standing. The White and Panjabi's method was used to measure the linear and angular displacements. Moreover, pain intensity was assessed using the visual analogue scale, and functional disability was investigated using a modified Oswestry Disability Questionnaire.

**Results:** The parameter of the linear displacement at the L3-L4 level was significantly different between the two groups (P=0.02). The mean duration of low back pain was longer in the LEIS, compared to the LFIS group (P=0.01).

**Conclusion:** In patients with LEIS, compensatory responses occur that cause less linear displacement at the L3-L4 level, compared to the patients with LFIS. Therefore, it is important to design appropriate exercises to better control the linear displacement at the L3-L4 level during the full range of motion in patients with LFIS.

**Level of evidence:** III

**Keywords:** Chronic low back pain, Extension impairment syndrome, Flexion impairment syndrome, Lumbar radiography

## Introduction

Low back pain is one of the most common musculoskeletal disorders,[1,2] compromising most patients referred to a physiotherapy clinic.[3] In general, low back pain is divided into specific and non-specific low back pain; the latter is more common.[4-9] Various classification, evaluation, and treatment approaches exist for non-specific low back pain.[8,10-17] Kinesiopathology model is a new rehabilitation model for the classification, evaluation, and treatment of non-specific back pain patients, which was proposed by Sahrmann and based on movement impairment syndromes. According to this model, continuous and repeated movements and postures with an incorrect pattern lead to musculoskeletal pain syndromes.[18] Sharman has divided low back pain of patients with movement impairment syndromes into four groups based on a series of clinical criteria, including lumbar flexion, lumbar extension, lumbar rotation with flexion, and lumbar rotation with extension syndromes.[18,19] Nowadays, Sahrmann's model is used to evaluate and treat patients with non-specific low back pain in many physiotherapy clinics.[18] However, research studies based on objective measurements, such as radiographic evidence, are scarce in this field to identify which radiographical findings are different between patients with lumbar flexion

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impairment syndrome (LFIS) and those with lumbar extension impairment syndrome (LEIS). Most studies are case reports and have been conducted directly concerning this model and the positive and beneficial effects of exercise therapy with a correction or treatment of movement impairment in patients with musculoskeletal pain syndromes (and not only in patients with low back pain) have been noted.[18,19] Studies have been performed to evaluate the degree of angular and linear displacement of the lumbar vertebrae and lumbar curvature in patients with mechanical low back pain (without dividing patients into specific subgroups).[20-24] so far, no study has been performed to compare the degree of angular and linear displacement of the lumbar vertebrae and lumbar curvature in patients with low back pain in the two subgroups of LFIS and LEIS. Recently, Malekmirzaei *et al*. used the same radiographic method in patients with low back pain in two subgroups of lumbar rotation with flexion, and lumbar rotation with extension syndromes.[25]

Up to now, the difference between the patients with LFIS and LEIS in terms of the kinematics of the lumbar spine has not been investigated. There is still uncertainty about whether the lumbar curvature and the degree of angular and linear displacement of the lumbar vertebrae are different between patients with LFIS and LEIS. A better understanding of the kinematic characteristics of the two groups of patients with movement impairment syndromes will help design the appropriate exercise therapy program. Therefore, this study aimed to compare the degree of angular and linear displacement of the lumbar vertebrae in patients with mechanical low back pain in two subgroups of LFIS and LEIS.

## Materials and Methods

The present cross-sectional and observational study was conducted on patients with mechanical low back pain who were referred to a physiotherapy clinic after being evaluated and diagnosed by a neurosurgeon (H.E.) in the hospitals affiliated to the Babol University of Medical Sciences. Then, the participants were examined and evaluated by two experienced physiotherapists with more than five years of experience in clinical practice using Sahrmann's movement impairment syndrome classification.[18,19] Patients were classified into FMIS and EMIS by a physiotherapist based on a series of physical examinations. These physical examinations were performed in standing position (quiet standing, forward flexion, and return from forward flexion), sitting position (lumbar in flexion, lumbar in extension and knee extension), supine position (hips and knee in extension, unilateral hip and knee flexion, and bilateral hip and knee flexion), prone position (with knees in extension, and with knees in flexion), and quadruped position with rocking backward.

Pain while bending forward was in favour of LFIS, while pain in returning from forward bending was in favour of LEIS. Patient pain in the supine position with reduced severity in knee flexion was considered LEIS; however, increased symptoms in knee flexion were considered LFIS. In the prone position, the patient's pain in knee flexion was in favor of EMIS. In the sitting position, increased lumbar flexion with pain and extension with decrease pain was in favour of LFIS. The quadruped position with rocking backward, increased pain intensity favored LFIS while decreased pain was considered LEIS.

The inclusion criteria were: 1) patients with low back pain for more than three months, 2) 18-46 years of age, 3) pain severity of 1-7 based on visual analogue scale (VAS),[22] and 4) LFIS and LEIS according to Sahrmann's model.[18] On the other hand, pregnant patients, those with mental health problems, epilepsy, history of spinal surgery, progressive osteoarthritis of the spine, moderate to severe spondylolisthesis, compression fracture of the spine, radiculopathy due to severe spinal canal stenosis, spinal tumours, obvious disc injury, and people who were not able to bend and straighten their back due to pain and spasm were excluded from the research procedure.[22,23]

Based on the pain or observation of the movement pattern disorder in a series of posture and movement tests, the subgroups of mechanical low back pain, LFIS, and LEIS were formed. Having experimented on 10 patients, the required sample size was calculated as 50 cases using G*Power software[22]. The purpose of the study was explained to the patients, and written informed consent was obtained, the contents of which had been approved by the Ethics Committee of Babol University of Medical Sciences (approval no. IR.MUBABOL.HRI.REC.1398.339). Demographic and clinical characteristics of the participants, including age, weight, height, gender, low back pain onset, and pain severity, were recorded in a form. The pain severity at rest was measured using the VAS. Scores on each scale ranged from 0 to 10, where 0 represented the best and 10 the worst conditions. The participants' duration of low back pain was asked and recorded on the demographic and clinical information form. At this stage, the participants completed the Persian version of the modified Oswestry Disability Questionnaire,[26] which consists of 10 sections of pain intensity, personal care, lifting, walking, sitting, standing, sleeping, sexual life (if applicable), social life, and traveling. Each section consisted of 6 items with a maximum score of 5. In each section, the first sentence has a score of 0, and the last sentence has a score of 5. Therefore, the total score ranges from 0 (least disability) to 50 (greatest disability).[27]

After the examination and evaluation, the participants were referred to the radiology department for radiography. The patient used protective shields to minimise the dose to the radiosensitive organs. Radiography of the lumbar spine was performed according to Merrill's method.[28] The radiography order was the same for all people, including the common positions of neutral, full extension, and full flexion while standing. White and Panjabi's method was used to measure linear and angular displacement.[29-34] To calculate the amount of angular displacement (vertebra rotation), the angle between the lower end of the upper vertebra and the upper end of the lower vertebra was measured. These measurements were performed both in full flexion and in full extension. Therefore, it was considered negative in flexion ($-\alpha$) and positive in extension ($\beta$). Then, the obtained values were subtracted from each other (using the formula: $\beta - (-\alpha)$). Three landmarks were utilised to calculate the sagittal linear displacement in flexion and extension. Firstly, a parallel line was drawn to the upper surface of the lower lumbar vertebra, which connected the two upper posterior and upper anterior edges of the vertebra. Secondly, a vertical line was drawn from the posterior upper edge of the lower vertebra to this line, which was considered the reference line. Thirdly, a line was drawn at the end of flexion and extension (a vertical line drawn from the lower edge of the upper vertebra on the horizontal line). Afterward, the distance between the two lines during extension (-b) and flexion (a) was calculated in millimeters (using the formula: a– (-b)) and considered the amount of sagittal displacement of the upper vertebra to the lower vertebra [Figure 1]. To calculate the lumbar lordosis using the Cobb method, an angle formed between the upper-end surface of the L1 to the lower-end surface of the L5 in the sagittal plane was utilised.[35] The measuring instruments in this study were a ruler and a conveyor, and the mean of three measurements was considered. To investigate the intra-observer reliability of the measures, two investigators with 12 years of experience in managing patients with low back pain who were blinded to the measurements assessed the radiographic images.

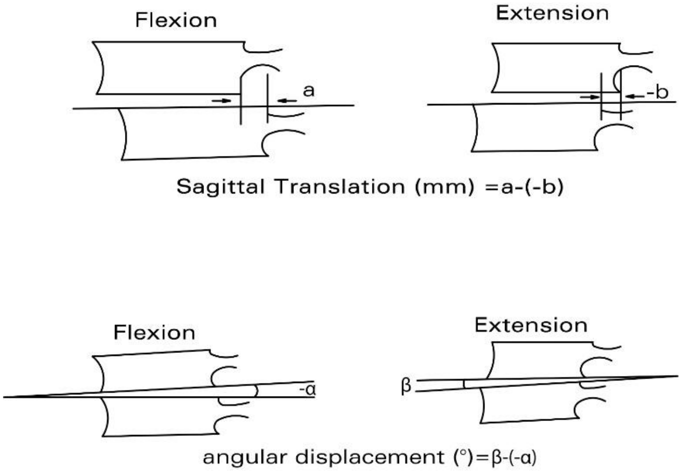


**Figure 1. Calculation of the linear and angular displacements of the lumbar vertebrae**

### *Statistical analysis*

Descriptive statistics are reported as mean, standard deviation, and range. The normality of data in each group was assessed using the Shapiro-Wilk test. Independent sample t-tests and Mann-Whitney U tests were used to compare the mean values of parameters of interest between the two groups. The linear and angular displacements distribution was not normal in all vertebrae levels. Therefore, the Mann-Whitney U test was used to compare the two groups. The independent sample t-test was utilised to compare other parameters. The intra-class correlation coefficient (ICC) with a 95% confidence interval was calculated to investigate the intra-observer reliability of radiographic measures. It is generally accepted that ICC lower than 0.5 represents an inadequate agreement, an ICC of 0.5 to 0.75 represents an adequate agreement, an ICC of 0.75 to 0.9 represents a good agreement, and an ICC higher than 0.90 represents an excellent agreement between the observers.[36] P-values below 0.05 were considered statistically significant. All statistical analyses were performed using the SPSS software program (version 17, SPSS Inc., Chicago, IL, USA).

## Results

The present study included cases with LFIS (n=25) and LEIS (n=25) (42 males and 8 females). The demographic characteristics of the studied participants are presented in [Table 1]. Regarding the intra-observer reliability of the radiographic parameters, the ICC values of all measurements were > 0.7 [Table 2]. There was a statistically significant difference between the two groups in terms of L3- L4 linear displacement (P=0.02). However, no statistically significant difference was observed in angular and linear displacements at other levels (P>0.05) [Table 3]. Considering the duration of low-back pain, the results showed a significant difference between the two groups of patients with LFIS and LEIS (P=0.01) [Table 4]. Further statistical tests revealed no statistically significant difference between the two groups (P>0.05) regarding pain intensity.

**Table 1. Demographic characteristics of the studied participants**

| Variables | Lumbar flexion syndrome | | Lumbar extension syndrome | |
|---|---|---|---|---|
| | Mean ± Standard deviation | Range | Mean ± Standard deviation | Range |
| Age (year) | 29.68 ± 1.53 | 20-42 | 29.12 ± 1.39 | 20-43 |
| Weight (Kg) | 76.04 ± 2.13 | 54-95 | 77.48 ± 2.45 | 40-97 |
| Height (cm) | 175.76 ± 1.84 | 155-188 | 174.88 ± 2.13 | 150-194 |

**Table 2. Intra-observer reliability of radiographic measures**

| | Flexion syndrome | Extension syndrome |
|---|---|---|
| **Radiographic measure** | **Intraclass correlation coefficient (95% confidence interval)** | **Intraclass correlation coefficient (95% confidence interval)** |
| L5-S1 linear displacement | 0.85 (0.44-0.96) | 0.92 (0.72-0.98) |
| L5-S1 angular displacement | 0.98 (0.93-0.99) | 0.94 (0.78-0.98) |
| L4- L5 linear displacement | 0.86 (0.44-0.96) | 0.80 (0.23-0.94) |
| L4- L5 angular displacement | 0.88 (0.55-0.97) | 0.79 (0.20-0.95) |
| L3- L4 linear displacement | 0.76 (0.13-0.93) | 0.97 (0.89-0.99) |
| L3- L4 angular displacement | 0.90 (0.54-0.97) | 0.94 (0.78-0.98) |
| L2-L3 linear displacement | 0.78 (0.16-0.94) | 0.97 (0.90-0.99) |
| L2-L3 angular displacement | 0.88 (0.39-0.96) | 0.79 (0.08-0.93) |
| L1-L2 linear displacement | 0.74 (0.12-0.93) | 0.98 (0.95-0.99) |
| L1-L2 angular displacement | 0.89 (0.49-0.96) | 0.86 (0.48-0.96) |

**Table 3. Comparison of the amount of radiological parameters of interest between the two groups**

| Variable | Flexion syndrome | Extension syndrome | Significance level |
|---|---|---|---|
| | Mean ± Standard deviation | Mean ± Standard deviation | |
| L5-S1 linear displacement (mm) | 3.24 ± 0.24 | 3.28 ± 0.32 | 0.94 |
| L5-S1 angular displacement (°) | 30.52 ± 1.47 | 34.08 ± 1.82 | 0.13 |
| L4- L5 linear displacement (mm) | 2.84 ± 0.23 | 3.14 ± 0.23 | 0.41 |
| L4- L5 angular displacement (°) | 26.86 ± 1.15 | 29.04 ± 1.19 | 0.12 |
| L3- L4 linear displacement (mm) | 3.46 ± 0.16 | 2.96 ± 0.26 | 0.02 |
| L3- L4 angular displacement (°) | 23.12 ± 0.82 | 23.64 ± 1.16 | 0.71 |
| L2-L3 linear displacement (mm) | 3.06 ± 0.24 | 3.00 ± 0.23 | 0.87 |
| L2-L3 angular displacement (°) | 19.64 ± 1.07 | 19.16 ± 1.28 | 0.77 |
| L1-L2 linear displacement (mm) | 2.84 ± 0.13 | 2.90 ± 0.22 | 0.91 |
| L1-L2 angular displacement (°) | 16.00 ± 0.66 | 16.16 ± 1.47 | 0.50 |
| Lumbar lordosis (°) | 54.08 ±10.37 | 49.92 ± 13.06 | 0.21 |

**Table 4.Comparison of the duration of low back pain between the two groups of lumbar extension syndrome and flexion syndrome**

| Variable | Average rating (month) | Significance level |
|---|---|---|
| The lumbar flexion syndrome | 20.38 | 0.01 |
| The lumbar extension syndrome | 30.62 | |

## Discussion

According to the literature, the displacement of the vertebrae during the full range of flexion and extension is higher in patients with a history of low back pain than those without low back pain. However, it has not been known whether the displacement rate is different among the mechanical subtypes of low back pain, including LFIS and LEIS. The present study was designed to investigate the linear and angular displacement of the lumbar spine vertebrae in patients with LFIS and LEIS. The primary finding of the present study was that the linear displacement at the L3-L4 level of the lumbar vertebrae is greater in patients with LFIS than in those with LEIS.

Until now, no study has compared the angular and linear displacements between patients with LFIS and LEIS. Hence, the results of the present study cannot be directly compared with previous studies. Hoffman et al. suggested that the tendency to flexion is higher in patients with low back pain with rotation impairment syndrome, compared to patients with the rotation-extension impairment syndrome group.[37] Moreover, Malekmirzaei et al. measured the angular and linear displacement of the lumbar vertebrae in 20 patients with chronic low back pain in two groups, extension-rotation impairment syndrome and flexion-rotation impairment syndrome. They concluded that the rate of linear displacement of the vertebrae in the L3-L4 lumbar vertebrae was greater in the extension-rotation group, compared to the flexion-rotation group.[24] The difference in the results of the present study and Malekmirzaei et al.'s study may be due to the difference in the type of movement impairment syndrome of the participants since patients were divided into the two groups of extension-rotation impairment syndrome and flexion-rotation impairment syndrome.

In contrast, in the present study, patients were divided into LFIS and LEIS groups. Patients with the extension-rotation impairment syndrome and flexion-rotation impairment syndrome have movement disorders in rotation (transverse plane) and extension and flexion (sagittal plane).[18] Therefore, kinematic or kinetic changes in these groups are not the same. On the other hand, the degree of defect or rotational disorder in the two groups of extension-rotation impairment syndrome and rotation-flexion impairment syndrome is not the same, which results in the more remarkable linear displacement of the vertebrae at the level of L3-L4 lumbar vertebrae in the rotation-extension syndrome group, compared to the flexion-rotation syndrome group. This difference can be possibly justified by the longer history of low back pain in the LEIS group.

The arthrokinematic control mechanisms of the vertebral displacement are impaired more remarkably in patients with LFIS than those with LEIS.[18] naturally, the control mechanisms of vertebrae sliding during flexion rely more on the posterior ligamentous elements, the orientation of the facet joints, and the fibres of the posterior annulus fibrosus. In contrast, the passive support of the vertebral column during extension relies more on bony restraints.[20] Given the prevalence of flexion injuries during activities, such as weight lifting, prolonged sitting positions, and driving, which apply flexion torque to the back, the possibility of damage to active and passive control mechanisms seems plausible.[38] Therefore, the linear displacement of vertebrae more commonly occurs in the direction of flexion rather than the extension. According to Panjabi's theory, neuromuscular control defects may change the neutral zone of a spinal segment.[20] Indeed, neuromuscular control is disturbed in patients with chronic back pain. In this case, the timing and intensity of the deep muscle activities (transversus abdominis and multifidus muscles) are disturbed; therefore, their effective role in providing the stability of the spinal column is disrupted.

Javadian et al. found that lumbar core stability exercises accompanied by general exercises decrease the excessive vertebral translation of the lumbar vertebrae.[22] Therefore, considering core stability exercises accompanied by general exercises may be an effective strategy to control the vertebral translation of patients with LFIS in clinical settings. It is noteworthy that the strength of the core stability muscles was not assessed in this study, which is an important issue for future research.

Some studies have shown that with the progression of chronic mechanical back pain, men are likely to develop self-stabilising mechanisms, reducing lumbar vertebral segmental displacement in these individuals.[39] Based on the results of the present study, lumbar lordosis, functional disability, and pain intensity were not significantly different between patients with LFIS and LEIS. However, a previous study has identified elevated lumbar lordosis as a cause of low back pain.[40] Furthermore, the results of a meta-analysis study in 2017 show that despite the association between lumbar lordosis and low back pain, there is no study suggesting the presence of low back pain due to reduced or increased lordosis; in fact, there is no causal relationship between lordosis and low back pain,[24] which is supported by the lack of difference in the rate of lordosis between the two groups of low back pain in the present study. On the other hand, some studies showed that factors, such as back pain intensity, age, and gender, could lead to differences in lumbar lordosis in patients with low back pain.[41,42] Considering that no significant differences were found in the present study regarding pain severity and functional disability between patients with LFIS and LEIS, it can be stated that the same rate of lordosis between the two groups is not improbable. However, this finding contradicted Norton et al.'s study, which showed a higher rate of standing lordosis in patients with low back pain due to LEIS.[43] This finding may be the case in some patients with low back pain with LEIS; however, usually, these people realise that the lordotic position will aggravate their symptoms. Thus, they try to keep the lumbar spine straight and reduce lordosis to reduce their symptoms.[18]

The present study had some limitations: 1) It was not possible to design computer software to measure the linear and angular displacement of the lumbar vertebrae during movement curvatures due to insufficient financial support, and 2) It was not possible to compare the rate of linear and angular displacement of the lumbar vertebrae in patients with low back pain and the control group due to the lack of a control group.

## Conclusion

The results of the present study revealed that the rate of linear displacement at the L3-L4 level during the full arc of motion was higher in patients with LFIS than in those with LEIS. No significant differences were found between the two groups in terms of pain severity, dysfunction, and lordosis. It seems that in patients with LEIS, compensatory mechanisms occur that cause more control over the amount of linear displacement at the L3-L4 level, compared to patients with LFIS. In addition, due to the greater linear displacement at the L3-L4 level, exercise therapy should be designed to emphasise more precise control of the displacement at this level. The measurement of kinematic variables using comprehensive software and the study of kinematic and morphological variables of muscles using MRI and ultrasound is recommended for a more detailed study of the kinematic variables of the vertebral column in patients with non-specific back pain with LFIS and LEIS.

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