# The different compensatory mechanism of sagittal spinopelvis in patients with LDH and patients with spondylolisthesis

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# Abstract

Background: few studies focusing on the differences of spinopelvic alignment between patients with LDH and patients with SPL were reported. The aim of this study was to study differences of spinopelvic alignment and to analyze differences of correlation between sagittal alignment parameters among patients with LDH and SPL, and normal population. Methods: Standard up-standing antero-posterior and lateral X-ray of the whole spine were preformed in all subjects. Evidence of LDH was confirmed by CT or MRI. SPL was diagnosed by X-ray or MRI. The parameters were measured included TK, LL, PI, SS, PT and SVA in lateral radiography.  Results: 60 patients with LDH, 62 patients with SPL and 57 normal were included. Significant differences as for the SS, TK, LL and SVA (P <0.05) was found among three groups. PI of SPL patients was the highest among the three groups (P <0.05). PT of both SPL patients and LDH patients were significant higher than controls' (P <0.05). LL of LDH patients was the lowest among the three groups (P <0.05). PI was less correlated with LL (P <0.05) in patients with LDH and SPL. PT was more strongly negative correlated with SS, LL and TK in LDH group (P <0.05). SS was more strongly positive correlated with TK (P <0.05), and SS and LL were more strongly negative correlated with SVA (P <0.05) in LDH patients.  Conclusion: Those results showed a disharmonious spinopelvic relationship and exhibited different compensatory models of spine to adapt changes in spinal alignment in LDH patients and SPL patients.


# Introduction

Sagittal spinopelvis shape plays an important role in occurrence and development in spinal disorders. Lumbar disc herniation (LDH) and spondylolisthesis (SPL) are becoming more and more common in clinical practice. Although sagittal spinopelvic unbalance was found in both patients with LDH and SPL [1–9]. To our knowledge, few studies focusing on the differences of spinopelvic alignment between patients with LDH and patients with SPL were reported [1, 2]. The objectives of our study were to analyze prospectively whether there were any differences in spinopelvic alignment among LDH patients and SPL patients, and non-symptom controls, and to investigate whether the correlations between sagittal alignment parameters change in those patients compared to controls.

# Methods

# Healthy subjects and patients

The present study was approved by the review boards of the Three Gorges University and Renmin hospital of Zhijiang. Adult volunteers were recruited from medical examination center of our hospital during a periodical health-screening scheme. Inclusion criteria were age (20–60 years), no previous spinal-related surgery, no history of back or leg pain, no spinal pathology, and no history of trauma and other local problems. Patients with LDH and SPL at orthopedic outpatient service and inpatient department were included from January 2016 to May 2018. The inclusion criteria for patients of the study were including: age (21–60 years), lower back or leg radicular symptoms, evidence of LDH or SPL

confirmed by magnetic resonance imaging (MRI) or computed tomography (CT), no previous spine surgery and injury. After signing informed consent of permitting their clinical data to be used for the study, these volunteers and patients were physical examination by two independent orthopaedic surgeons, then standard up-standing lateral and antero-posterior X-ray of the whole spine were carried.

# Radiographic measurements

SPL and LDH characteristics included age, gender, lesion location and degree. The radiographic parameters measured included pelvic incidence (PI), thoracic kyphosis (TK), lumbar lordosis(LL), sacral slope (SS), pelvic tilt (PT) and sagittal vertical axis from C7 PL (SVA)[10]. TK was defined by the inferior end plate of T12 and superior end plate of T5. LL was measured by the superior end plates of S1 and L1. TLK was defined by the superior end plates of T10 and inferior end plate of L2. PI was the angle between the vertical line to the upper sacral endplate at its midpoint and the line linking this point with the femoral head axis. The SS was the angle between the horizontal line and the upper endplate of sacral. The PT was determined by the line through the midpoint of the sacral plate to the femoral head axis. The SVA was the horizontal distance from the C7 plumb line to the postero-superior corner of S1. If C7PL was behind postero-superior corner of S1, SVA was considered negative. While, If C7PL was ahead of postero-superior corner of S1, SVA was considered positive.

# Statistical analysis

Fisher's exact test was used to analyze the gender difference between Group LDH and Group SPL. One-way analysis of variance (ANOVA) was used to analyze differences of spino-pelvic parameters among Group LDH, Group SPL and control group. For any statistical significance obtained in the ANOVA, differences between any two groups among the three groups were tested further by the Tukey's studentized range (HSD) test. Pearson's correlation coefficient was performed to analyze correlations between two variables. $P<0.05$ was considered statistically significant.

## Results

A total of 60 patients with LDH, 62 patients with SPL and 57 normal (average age: 40.1/41.6/36.8years, respectively; male/female: 38/22, 14/48, 25/32, respectively) were included. 36, 27 and 3 patients with LDH located at L4/5, L5/S1 or Bilateral sides, respectively (table 1). There were 41, 17 and 4 patients with SPL locating at L4, L5 or L3, respectively. And I/II degree of SPL was found in 46/16 patients.

Among LDH, SPL and controls group (table 2), SS was 24.77˚, 35.94˚ and 31.61˚, respectively；TK was 13.15˚, 34.82 and 23.83˚, respectively, SVA was 37.13 mm, 17.81 mm and –3.37 mm, respectively. There were significant differences among three groups in the SS, TK, LL and SVA absolute value (P <0.05). As for PI, SPL patients were significant higher than those of controls and LDH patients (P <0.05). However, no notable difference was found between LDH patients and controls. As for PT, both SPL patients and

LDH patients were significant higher than those of controls (P <0.05). However, no notable difference was found between LDH patients and SPL patients. As for LL, LDH patients were significant lower than both those of controls and SPL patients (P <0.0001). And, SPL patients were notable higher than controls(P <0.0001).

Significant correlations were found between several spino-pelvic parameters (Table 3). The degrees of correlations, However, between the spinopelvic parameters differed in the three groups. When the Group LDH and SPL compared with controls, PI was less correlated with LL (r = 0.352/0.482/0.618, respectively) and SS (r = 0.514/0.691/0.875, respectively) (P <0.05). PT was more strongly negative correlated with SS, LL and TK in LDH group when compared to controls and SPL group (P <0.05). In LDH group, SS was more strongly positive correlated with TK (P <0.05), and SS and LL were more strongly negative correlated with SVA (P <0.05).

# Discussion

Spino-pelvic alignments of the general population, patients with LDH, and with SPL have been studied in past decades [1, 2]. In clinical practice, LDH patients sometimes present with a forward-bending posture, but SPL patients are sometimes with forward-backing posture [11, 12]. There are some studies on sagittal spinal alignment of LDH and SPL. However, the differences of sagittal spinal alignment between LDH patients and SPL patients have not been quantified at length.

PI has been known to be stabilized and have no further change after adult stage. There is a geometrical relation between the PI and the two positional parameters as well as PI = PT+SS[13–15]. Many studies reported an association between PI and SPL[4, 16, 17]. These authors have noted all patients with SPL have a higher PI and SS, which indicated the increased PI may predispose to SPL, and also indicated pelvic alignments may have a direct effect on the progress of a SPL. The present results showed PI in SPL patients is significantly larger than that of normal, which indicates these parameters may be an important factor causing SPL. PI normal reaction hip located below L5 positive anatomical relationship, sagittal balance is destroyed in patients with SPL, to compensate this change, the pelvis rotates gradually leading to the pelvis and sacrum vertical, hip joint forward displacement exceeding lumbosacral joint, thus increasing the LL, so gravity line is still above the hip, to establish a new balance[8, 15]. In the up-standing posture of normal, the body accommodates the sacral tilt forward (as well as SS) through the LL changes. In order to maintain balance, LL becomes larger, and SS is greater, the shearing force by lumbosacral joint becomes greater, therefore, may cause SPL occurrence even progress. In this study, the high SS and PT found in the SPL group suggested that the pelvis rotates anterior-ward and the spatial orientation of sacrum is more horizontal than those of the normal population.

No obviously difference of PI between patients with LDH and controls, which shows PI was not important factor in LDH occurrence and development. The small SS and high PT found in the LDH group suggested that the pelvis rotates backward and the sacrum was more vertical than those of the normal population. In addition, an increasing PT may be an action of compensation for the loss of LL. The loss of LL in LDH

may be secondary to factors resulting to disc height loss. And a change of forward-bending postural may be an analgesic response in order to avoid high pressure of posterior disc, or to avoid foraminal stenosis caused by herniated disc [2]. The LL loss may also be root in a rotation of the pelvis caused by contraction of the hip extensor muscles [18]. The LL loss, biomechanically, could lead to antedisplacement of the C7 PL and a more vertical PT as well as PT increases found in the present study, and PT increases could be a compensation for the anterior displacement of C7 PL.

Previous studies [5, 19, 20] have demonstrated the correlations of sagittal spinopelvis both in normal population and spinal degenerative diseases. Our results showed that significantly positive correlations were found between PI and LL, PI and SS, LL and SS in either patients with LDH or SPL or normal subjects, the trends between PI and LL, PI and SS are decrease, and between LL and SS is increase. A high PI will accompany with a high PT and/or SS because PI is the summation of PT and SS, and a high SS is more inclined to a high LL in order to compensate and maintain the trunk focused over the bilateral femoral heads. As compared to the control population, the loss of TK in patients with SPL is presumably secondary to the increased LL. However, as compared to the control subjects and SPL patients, the decreased TK in patients with LDH was probable another compensation phenomenon in response to decreased LL. Therefore, the present results indicated that the higher LL of SPL clearly was secondary to the high PI and was an important factor inducing high shearing moment of the inter-articularis. a forward-bending posture while walking in patients with LDH was an important factor for the lower LL. The correlations between PT and LL, TK and SS were poor in normal subjects and in SPL patients. However, those correlations were noted in patients with LDH. The correlation between spinal saggital parameters and SVA was independent in the control population. However, the SVA in the LDH group was affected by spinopelvic parameters. Those results showed a disharmonious spinopelvic relationship and exhibited model of spinal-pelvic compensation to adapt changes in spinal alignment in patients with disc herniation. The SVA of SPL patients was associated obviously with PT and LL, showing the whole balance of alignment spine was compensated by LL in SPL patients.

There are several limitations to this study. First, the number of patients was small, and further larger patient cohorts studies are required to confirm the different compensation. Second, the patients with SPL and LDH were not located at the same level which might inference the present results.

## Conclusions

The results of the present study indicated a disharmonious spinopelvic relationship and exhibited different compensatory models of spine to adapt changes in spinal alignment in LDH patients and SPL patients.

## Declarations

# Ethics approval and consent to participate

The present study was approved by the review boards of the Three Gorges University and Renmin hospital of Zhijiang. All participators signed informed consent of permitting their clinical data to be used for the study.

# Consent for publication

The authors report no conflict of interest concerning the materials or methods used in this study or findings specified in this paper. The authors have reviewed the final version of the manuscript and approve it for publication

# Availability of data and material

All data generated or analysed during this study are included in this published article

# Competing interests

The manuscript submitted does not contain information about medical drug(s). No funds were received in support of this work. The authors declare that they have no competing interests.

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# Authors’ contribution

The authors report no conflict of interest concerning the materials or methods used in this study or findings specified in this paper. Author contributions to the study and manuscript preparation include the following. Conception and design: WF W. clinical assessment: WF W, K N, Y C, Z Y, N R, F Z, J L. Data analysis: K N, Y C, Z Y. Drafting the article: WF W, Z Y, N R, F Z. Critically revising the article: WF W, K N. Reviewed final version of the manuscript and approved it for submission: all authors. Study supervision: K N.

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Not Applicable

## Abbreviations

LDH: lumbar disc herniation, SPL:spondylolisthesis, MRI: magnetic resonance imaging, CSVL: central sacral vertical line, PL: C7 plumb line, TK: thoracic kyphosis, LL: lumbar lordosis, PI: pelvic incidence, SS: sacral slope, PT: pelvic tilt, SVA: sagittal vertical axis

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# Tables

Table 1: Patient's anthropomorphic characteristics

| | | LDH patients | SPL patients | Controls |
|---|---|---|---|---|
| n | | 60 | 62 | 57 |
| Age (SD) (years) | | 40.05(12.60) | 41.60(12.46) | 36.79(13.00) |
| Sex (%) | Male | 63.33 | 22.58 | 43.86 |
| | Female | 36.67 | 77.42 | 56.14 |
| L4/5 or L4 | | 36 | 41 | -- |
| L5/S1 or L5 | | 17 | 17 | -- |
| Bilateral or L3 | | 8 | 4 | -- |
| I/II degree | | -- | 46/16 | -- |
| Degenerative/Isthmic SPL | | -- | 31/31 | -- |

Notes: For parameter mean and SD are showed. LDH: lumbar disc herniation, SPL: spondylolisthesis. L: lumbar, S: sacral

Table 2: Differences in spinopelvic parameters between the patients with LDH and SPL, and the controls

| | PI° | PT° | SS° | LL° | TK° | SVA(mm) |
|---|---|---|---|---|---|---|
| LDH patients | 45.10¥ (8.90) | 20.33£ (8.78) | 24.77§ (8.90) | 28.67§ (17.45) | 13.15$ (11.51) | 37.13δ (42.33) |
| SPL patients | 55.44¥# (11.54) | 19.76& (8.25) | 35.94§ (10.13) | 59.00§ (14.10) | 34.82$ (11.73) | 17.81δ (35.32) |
| Controls | 47.25# (11.35) | 15.63£& (5.50) | 31.61§ (9.97) | 48.59§ (10.05) | 23.83$ (9.52) | -3.37δ (27.74) |

Notes: For each parameter mean and SD are showed. LDH: lumbar disc herniation, SPL: spondylolisthesis. ¥, #, £ and & indicate significant difference between two groups ($P$ <0.05), §, $and δ indicate significant difference between any two groups among the three groups ($P$ <0.05). TK: thoracic kyphosis, LL: lumbar lordosis, PI: pelvic incidence, SS: sacral slope, PT: pelvic tilt, SVA: sagittal vertical axis.

| Table 3: Correlations between several spinopelvic parameters in the three groups. | | | | | | |
|---|---|---|---|---|---|---|
| | LDH patients | | SPL patients | | Controls | |
| | r | *P* value | r | *P* value | r | *P* value |
| PI-PT | 0.493 | **0.000** | 0.538 | **0.000** | 0.477 | **0.000** |
| PI-SS | 0.514 | **0.000** | 0.691 | **0.000** | 0.875 | **0.000** |
| PI-LL | 0.352 | **0.006** | 0.482 | **0.000** | 0.618 | **0.000** |
| PI-TK | 0.173 | 0.187 | -0.002 | 0.986 | 0.172 | 0.200 |
| PI-SVA | -0.119 | 0.367 | 0.147 | 0.255 | 0.257 | 0.053 |
| PT-SS | -0.493 | **0.000** | -0.214 | 0.095 | -0.009 | 0.948 |
| PT-LL | -0.547 | **0.000** | -0.277 | **0.029** | -0.070 | 0.603 |
| PT-TK | -0.485 | **0.000** | -0.230 | 0.072 | 0.017 | 0.902 |
| PT-SVA | 0.342 | **0.007** | 0.277 | **0.029** | -0.008 | 0.950 |
| SS-LL | 0.891 | **0.000** | 0.756 | **0.000** | 0.742 | **0.000** |
| SS-TK | 0.650 | **0.000** | 0.205 | 0.110 | 0.187 | 0.164 |
| SS-SVA | -0.456 | **0.000** | -0.046 | 0.721 | 0.297 | **0.025** |
| LL-TK | 0.751 | **0.000** | 0.538 | **0.000** | 0.500 | **0.000** |
| LL-SVA | -0.646 | **0.000** | -0.421 | **0.001** | 0.139 | 0.303 |
| TK-SVA | -0.329 | **0.010** | -0.055 | 0.669 | 0.149 | 0.267 |

Notes: LDH: lumbar disc herniation, SPL: spondylolisthesis. TK: thoracic kyphosis, LL: lumbar lordosis, PI: pelvic incidence, SS: sacral slope, PT: pelvic tilt, SVA: sagittal vertical axis.

# Figures

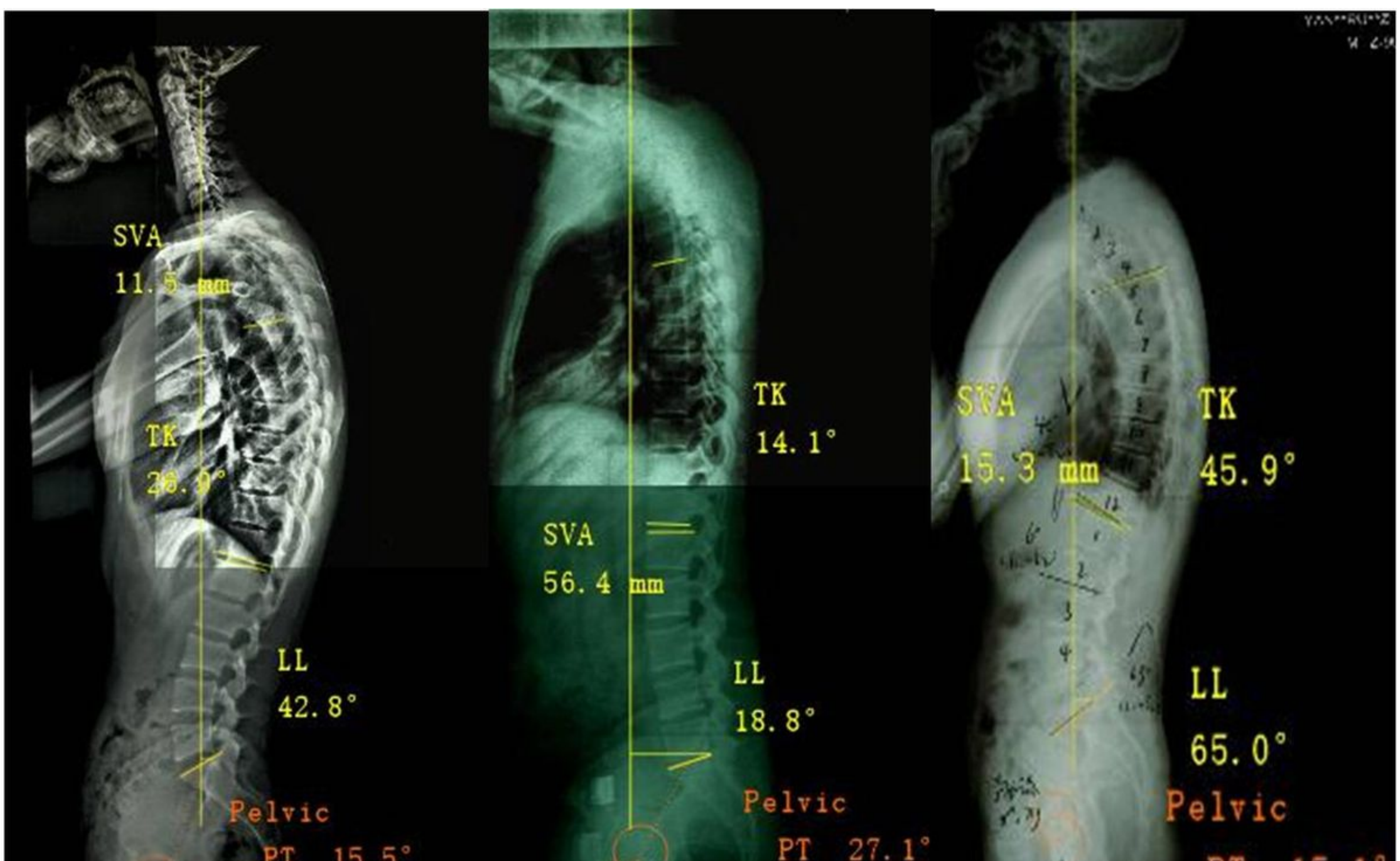


Figure 1

The examples of spinopelvic morphology in control, LDH patient and SPL patients. A figure is a spinopelvic plane of control, B figure is a a spinopelvic plane of LDH patient, and C figure is a spinopelvic plane of SPL patients. TK: thoracic kyphosis, LL: lumbar lordosis, PI: pelvic incidence, SS: sacral slope, PT: pelvic tilt, SVA: sagittal vertical axis. The parameters are showing in figures: