The relationship between spinopelvic parameters and clinical symptoms of severe isthmic spondylolisthesis: a prospective study of 64 patients

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Abstract

Purpose To investigate the relationship between spinopelvic parameters and clinical symptoms for patients with severe isthmic spondylolisthesis.

Methods A series of spinopelvic parameters were measured in 64 patients with L5 severe isthmic spondylolisthesis. The patients were divided into two groups according to Oswestry score obtained preoperatively, i.e. mild or severe low back pain group. *T* test was used to compare parameters between two groups, and multiple linear regression analysis was employed to investigate the association between parameters and Oswestry score.

Results Compared with two group patients, parameters of spondylolisthesis grade, pelvic tilt (PT), lumbar lordosis (LL), T9 tilting angle (T9TA), sacro-femoral horizontal distance (SFHD), distance between perpendicular line through C7 and sacrum (SC7D), pelvic tilt/sacral slope (PT/SS), sacro-femoral horizontal distance/vertical distance (SFHD/SFVD), and lumbar lordosis/thoracic kyphosis (LL/TK) were significantly increased in severe low back pain group, while SS and SFVD were significantly decreased, and no significant difference was found for pelvic incidence (PI) and TK. The statistical analysis showed that spondylolisthesis grade, PT, SC7D, LL, SFHD, PT/SS, SFHD/SFVD, and LL/TK had a significant positive correlation with Oswestry score, with an order of spondylolisthesis grade > PT/SS > SC7D > PT > SFHD/SFVD > SFHD > LL/TK > LL. No significant correlation was found for PI, TK, T9TA with Oswestry score, while SS

and SFVD had a significant negative correlation with Oswestry score, with an order of SS > SFVD.

Conclusions The spinopelvic parameters (spondylolisthesis grade, SS, PT, SC7D, LL, SFVD, SFHD, PT/SS, SFHD/SFVD, LL/TK) are significantly correlated with clinical symptoms of severe isthmic spondylolisthesis in patients. The association of the exacerbation of low back pain with SS (correlation coefficient -0.981 , strong) and SFVD (correlation coefficient -0.802 , strong) is the most significant correlation.

Keywords Severe isthmic spondylolisthesis · Spinopelvic parameter · Clinical symptom

Introduction

Severity of isthmic spondylolisthesis is usually assessed by image grading. However, the degree of patient's clinical symptoms does not always correspond to the results of image grading, which indicates that other factors besides spondylolisthesis grade may also affect the symptoms of isthmic spondylolisthesis. Duval-Beaupère first applied barycentremetrical (an experimental instrument for the evaluation of the gravity center position of human body segments, which utilizes absorbing gamma rays) to study the location of the gravity line of the human body [1, 2]. The use of this device clarifies the normal location of the gravity line of the human body and the influence of it on weight loading of the lumbosacral portion [1, 2]. Recently, a number of researchers reported that the parameters of pelvic morphology and the spine curve in the sagittal plane, e.g. pelvic incidence and lumbar lordosis, had a large influence on isthmic spondylolisthesis and its progression [3–6, 10, 12, 13]. However, the relationship between the

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spinopelvic parameters and the clinical symptoms of isthmic spondylolisthesis has not been fully investigated in previous studies.

Clinically, the patients with mild isthmic spondylolisthesis (Meyerding grade I–II) can be treated conservatively in many instances, but the highgrades (Meyerding grade III–IV) should demand surgery more often than the lower ones to reduced the risk of progression or ease the pain [7, 8]. In the present study, we collected the image information of 64 patients with severe isthmic spondylolisthesis on L5 (Meyerding grade III–IV), and measured the spinopelvic parameters, which were then compared with the Oswestry scores on low back pain obtained preoperatively. As a consequence, the potential relationship between variation of spinopelvic parameters and the clinical symptoms of isthmic spondylolisthesis was analyzed.

Patients and methods

Patients

A total of 64 patients with severe isthmic spondylolisthesis on L5 were admitted to The Second Xiangya Hospital of Central South University from 2006 to 2012. The present prospective study was approved by the Ethics Committee of the hospital, and all patients provided written informed consent. The patients who met the following criteria were excluded from the present study: (1) any history of lumbar surgery (including excision of the intervertebral disc); (2) lumbar disease (including traumatic compression fractures, tumors, degenerative lumbar spondylolisthesis or multi-segmental spondylolisthesis, spinal canal stenosis or disc herniation of other segments); (3) lumbar scoliosis; (4) hip joint disorder or lower limb disease.

Among these patients were 34 males and 30 females, ranging in age from 13 to 65 years (average age 44.5). Forty-seven patients had isthmic spondylolisthesis with Meyerding grade III and seventeen with Meyerding grade IV. The average spondylolisthesis percentage was 69 %. The Oswestry score of low back pain was obtained for the patients preoperatively. In addition, the antero-posterior and lateral radiographs of the spine (including C7 and hip joint) were collected for the patients in erect position with bilateral knee joints straight.

Definition of imaging parameters

The parameters reflecting pelvic morphology and full-spine curve in the sagittal plane were measured using spinal radiographs including pelvic parameters and spinal parameters.

Pelvic parameters

As shown in Fig. 1a, the pelvic parameters include pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), sacro-femoral horizontal distance (SFHD) and sacro-femoral vertical distance (SFVD). The definitions of these parameters are as follows.

PI: the angle between the perpendicular bisector of S1 endplate and the line connecting midpoints of S1 upper endplate and center of femoral heads,

PT: the angle between the line connecting midpoints of S1 upper endplate and center of femoral heads and the perpendicular line,

SS: the angle between the tangent of S1 endplate and the horizontal line,

SFHD: the horizontal distance between center of femoral heads and S1,

SFVD: the vertical distance between center of femoral heads and S1.

The relationship between these three angles are $PI = PT + SS$. PI describes quantitatively the anatomical and morphological features of pelvis and hip joint, and the increase of PI has been confirmed to contribute to spondylolisthesis and its progression [3–6, 10, 12, 13]. The position of sacrum and pelvis can have changes of anterior tilt and posterior tilt on axis of hip joint, and PT and SS change accordingly. The ratio between these two parameters, i.e. PT/SS, can reflect the changes of sacrum–pelvis spatial position and orientation. SFHD and SFVD are quantitative indexes of the distance between sacrum and center of femoral heads, and the ratio of SFHD/SFVD reflects spatial position change of sacrum and hip joint. Of great significance in the evaluation of patients before and after surgery, the ratio between the parameters of PT/SS and SFHD/SFVD may also indirectly reflect the severity of lumbosacral kyphosis in patients with severe spondylolisthesis.

Spinal parameters

As shown in Fig. 1b, the spinal parameters include lumbar lordosis (LL), thoracic kyphosis (TK), SC7D, and T9 tilting angle. The ratio of LL/TK reflects the shape of full-spine curve. T9 tilting angle (T9TA) is defined as the angle between the line connecting midpoint of T9 and hip joint and the perpendicular line [14]. SC7D is defined as the horizontal distance between the perpendicular line through C7 and the posterior corner of the sacrum.

All the measurements were conducted by the same physician. Data were obtained as the average values of three measurements excluding those in blurred radiographs. Patients completed the Oswestry score sheet

Fig. 1 Schematic image showing definition of **a** pelvic parameters and **b** spinal parameters

preoperatively after being given explanations by the same physician.

Statistical analysis

The patients with isthmic spondylolisthesis are divided into two groups according to the severity of low back pain symptom, i.e. mild (Oswestry score from 0 to 22) and severe (Oswestry score from 23 to 45). *T* test is used to compare the difference for each parameter in these two groups using SPSS software, and the correlation between each parameter and the Oswestry score is analyzed through multiple linear regression analysis, which is determined by the value of correlation coefficient, i.e. weak (0.2–0.4), moderate (0.4–0.6), and strong (0.6–1.0). The difference is significant when the *P* value is less than 0.05.

Results

According to the Oswestry score obtained for the patients preoperatively, 31 patients had mild low back pain symptoms with a mean Oswestry score of 15.6 ± 5.4 , and the

other 33 patients had severe low back pain symptoms with a mean Oswestry score of 28.8 ± 5.5 . The information for the parameters measured for the patients are shown in Table 1. There is no significant difference for PI and TK between the two groups. However, the parameters of spondylolisthesis grade, PT, LL, T9 tilting angle, SFHD and SC7D were significantly increased in the patients in the severe low back pain group compared to the patients in the mild low back pain group ($P < 0.05$). In addition, the parameters of SS and SFVD are significantly decreased in the patients in the severe low back pain group compared with the mild low back pain group ($P < 0.05$). The parameters of PT/SS, LL/TK, and SFHD/SFVD are presented in Table 2, and all these parameters are significantly increased for the patients in the severe low back pain group compared to the patients in the mild low back pain group ($P < 0.05$).

The results of the association between each parameter and the Oswestry score based on the multiple linear regression analysis are shown in Table 3. The parameters of spondylolisthesis grade, PT, SC7D, LL, and SFHD were significantly positively correlated with the Oswestry score ($P < 0.05$). The degree of each parameter's contribution to

Table 1 Comparison of the parameters measured for the patients in the mild and severe low back pain group

Parameters	Oswestry score (0–22, mild) <i>n</i> = 31	Oswestry score (23–45, severe) <i>n</i> = 33	<i>P</i> value
Average of Oswestry score	15.6 ± 5.4	28.8 ± 5.5	<0.05
Average of spondylolisthesis grade	62.8 ± 10.4	74.5 ± 11.5	<0.05
PI	74.6 ± 11.6	77.9 ± 12.7	No significant difference
SS	52.3 ± 9.4	44.5 ± 9.0	<0.05
PT	22.3 ± 6.3	33.4 ± 8.1	<0.05
LL	56.5 ± 10.2	68.2 ± 11.7	<0.05
TK	41.2 ± 8.2	37.6 ± 7.4	No significant difference
SFHD	44.9 ± 10.3	53.5 ± 10.8	<0.05
SFVD	109.5 ± 15.6	81.1 ± 11.7	<0.05
T9 tilting angle (T9TA)	−7.8 ± 4.8	−2.0 ± 1.5	<0.05
SC7D	23.2 ± 34.3	41.4 ± 37.4	<0.05

Table 2 Comparison of the ratios of PT/SS, LL/TK, and SFHD/SFVD for the patients in the mild and severe low back pain group

Oswestry score	PT/SS	LL/TK	SFHD/SFVD
0–22, mild, <i>n</i> = 31	0.42 ± 0.11	1.36 ± 0.35	0.41 ± 0.08
23–45, severe, <i>n</i> = 33	0.74 ± 0.16	1.81 ± 0.39	0.66 ± 0.13

the Oswestry score variation is as follows: spondylolisthesis grade (correlation coefficient 0.229, weak) >SC7D (correlation coefficient 0.225, weak) >PT (correlation coefficient 0.212, weak) >SFHD (correlation coefficient 0.154, weak) >LL (correlation coefficient 0.130, weak). The parameters of PI, TK, and T9 tilting angle are not significantly correlated with the Oswestry score ($P > 0.05$), while SS and SFVD had a significant negative correlation with the Oswestry score ($P < 0.05$), with SS (correlation coefficient −0.981, strong) having a greater degree of contribution to the Oswestry than SFVD (correlation coefficient −0.802, strong). The parameters of PT/SS, LL/TK, and SFHD/SFVD also have significantly positive correlations with the Oswestry score ($P < 0.05$) with a relationship of PT/SS (correlation coefficient 0.234, weak) >SFHD/SFVD (correlation coefficient 0.190, weak) >LL/TK (correlation coefficient 0.137, weak). However, the contribution of these three ratios to the Oswestry score is greater than that of any single parameters.

Table 3 Multiple linear regression analysis showing the correlation between the measured parameters and Oswestry score

Independent variable	Dependent variable	Estimate of coefficient	<i>T</i> statistics	<i>P</i> value
Spondylolisthesis grade	Oswestry	0.229	2.435	0.009
PI	Oswestry	−0.207	−1.026	0.154
SS	Oswestry	−0.981	−2.503	0.007
PT	Oswestry	0.212	1.974	0.026
LL	Oswestry	0.130	2.353	0.011
TK	Oswestry	−0.082	−0.781	0.219
SFHD	Oswestry	0.154	2.115	0.019
SFVD	Oswestry	−0.802	−2.684	0.005
T9 tilting angle (T9TA)	Oswestry	0.538	0.497	0.310
SC7D	Oswestry	0.225	2.644	0.005
PT/SS	Oswestry	0.234	1.870	0.033
LL/TK	Oswestry	0.137	2.251	0.014
SFHD/SFVD	Oswestry	0.190	1.746	0.043

Spondylolisthesis grade, PT, SC7D, LL, SFHD have significantly positive correlation with Oswestry score, while SS and SFVD are significantly negative correlated with Oswestry score

Discussion

There are many factors affecting the clinical symptoms of spondylolisthesis and there is great variability among patients in the symptoms of low back pain. Factors such as age, gender, job and personal perception of pain all have influence on the symptoms. Our study demonstrates the important impact of spinal–pelvic parameters, and their ratios, on the clinical symptoms of patients with severe spondylolisthesis. The objectives of this study were: (1) to determine the subset of patients in which the clinical symptoms may progress, requiring surgery, and the subset of patients for whom conservative treatment can be adopted; and (2) to provide a reliable approach and a basis for post-operative radiological evaluation and to determine possible predictors of unsatisfactory outcomes.

The parameters of the pelvic and spinal morphologies have been shown to be related to isthmic spondylolisthesis. Results of the present study indicate that there was a significant difference with regard to some of these parameters between the patients with mild low back pain group and those with severe low back pain group. As shown in Fig. 2a, the features of pelvic spatial position and sagittal plane curve of the full spine for the patients in the mild low back pain group are: anterior pelvic tilt (decreased PT/SS), decreased SFHD/SFVD as a result of a decreased SFHD and an increased SFVD, decreased lumbar lordosis (decreased LL/TK), decreased trunk anterior tilt (decreased

Fig. 2 **a** The curve of pelvis and full spine in sagittal plane for a patient in the “compensation” state; **b** the curve of pelvis and full spine in sagittal plane for a patient in the “decompensation” state

T9 tilting angle and SC7D). On the contrary, as shown in Fig. 2b, the features of pelvic spatial position and sagittal plane curve of the full spine for the patients in the severe low back pain group are: posterior pelvic tilt (increased PT/SS), increased SFHD/SFVD as a result of a large value SFHD and a decreased value of SFVD, obvious increase of lumbar lordosis (large LL/TK), trunk anterior tilt (increased T9 tilting angle and SC7D). The difference in the sagittal plane curve in these two groups reflects the two mechanical equilibrium states of “compensation” and “decompensation”. The patients with spondylolisthesis in the “decompensation” state have more severe symptoms than those in “compensation” state. These results indicate that the parameters of PT/SS, SFHD/SFVD, LL/TK, SC7D and spondylolisthesis grade are the key factors to determine the mechanical equilibrium state and symptoms of the patient.

The pelvic and spinal parameters were previously used to classify subtypes for the patients with spondylolisthesis. Based on a study of 133 patients with severe developmental spondylolisthesis, Hresko et al. [16] also proposed two subtypes of severe developmental spondylolisthesis according to SS and PT value, i.e. balanced pelvis or anterior pelvic tilt (PT is decreased, while SS is large) and unbalanced pelvis or posterior pelvic tilt (PT is large, while SS is decreased). They found that the SS and PT values of the patients with severe spondylolisthesis in the balanced pelvis subtype were similar to that of normal individuals

whose PI value was above 70, while there was significant difference with regard to the SS and PT values between the other subtype, i.e. the unbalanced pelvis, and the normal individuals. Labelle et al. [17] also suggested that two subtypes of low developmental isthmic spondylolisthesis be applied according to the PI and SS value. There is one specific subtype with low PI and SS (nutcracker subtype), and another with near normal PI and SS, both of which are associated with distinct pelvic, lumbosacral and lumbar alignment. Duval-Beaupère and his group, in the study evaluating the normal gravity line of human body, found that the ideal gravity line is located in front of the anterior edge of T9 vertebra at an average 15.5 mm and behind the lumbar vertebra and hip joint in lumbosacral segment, running through the posterior part of sacrum, and lying behind the midpoint of endplate of sacrum at an average 14 mm. Legaye and Duval-Beaupère stated that the spinal curve can be divided into two types according to the positions of the spinal column and the line of gravity. One is the economically steady sagittal shape, in which gravity projects behind the lumbar vertebral structures and the femoral heads. The other is the non-economical sagittal shape, with gravity projecting in front of the lumbar structures and the femoral heads. Under the economical sagittal curve, no obvious electrophysiological activity was found in the lower back. The ideal gravity line position enables the body to assume a more economical standing posture, which in turn reduces the weight loading of lower

back muscles and pains [1, 2, 13–15]. In the present study, we found that the gravity line position of patients with severe spondylolisthesis to be of a “compensatory” type and the ratio between the parameters was closer to the economical sagittal curve. Mac-Thiong et al. [18] performed a comparative study on low developmental isthmic spondylolisthesis and high developmental isthmic spondylolisthesis, and divided high spondylolisthesis into balanced pelvis and unbalanced pelvis on the basis of SS. They worked out a model on the association among the parameters of full-spine curve in the two groups and found that the parameters of the normal individuals, the low spondylolisthesis group, and the balanced pelvis of high spondylolisthesis group all had similar association of parameters, but all were significantly different from the association of parameters in unbalanced pelvis of high spondylolisthesis group. However, in all of these studies, only simple imaging measurements were performed without exploring the relationship between the imaging parameters and the patient’s clinical symptoms. In addition, it was not clear whether there is a significant difference between the patient’s clinical symptoms amongst the different subtypes and specific standards for subtype classification were not well defined. Based on the analysis of the results on L5 spondylolisthesis spinopelvic parameters reported by the Spinal Deformity Study Group (SDSG), Labelle et al. proposed more specific methods of classification. They suggested that three important factors should be taken into account in terms of spondylolisthesis classification: (1) degree of spondylolisthesis (mild or severe); (2) PI angle (small, normal, large); (3) balance state of full spine–pelvis (balanced or unbalanced). In this study, it was proposed that mild spondylolisthesis (spondylolisthesis grade <50 %) and severe spondylolisthesis (spondylolisthesis grade >50 %) should be identified first, followed by measurement of the parameters such as PI, SS, PT and C7 perpendicular line. Since most mild spondylolisthesis corresponds to balanced curve, it can be divided into three subtypes: (1) small PI type (PI < 45°); (2) normal PI type (45° < PI < 60°); (3) large PI type (PI > 60°). Based on the balance state of the trunk and pelvic tilt, severe spondylolisthesis can be divided into three subtypes: (1) balanced type; (2) pelvic posterior tilt balanced type; (3) pelvic posterior tilt unbalanced type [19–21].

In the present study, the multiple linear regression analysis indicated that severity of low back pain was significantly positively correlated with spondylolisthesis grade, LL, SC7D, PT, SFHD, PT/SS, SFHD/SFVD, and LL/TK, significantly negatively correlated with SS and SFVD, and there was no significant correlation with PI, TK and T9 titling angle. In addition, the parameters of SC7D, spondylolisthesis grade, PT/SS, SFHD/SFVD, and LL/TK can not only determine the patient’s mechanics

equilibrium, but are also related to the symptoms of low back pain directly. Duval-Beaupère and Legaye presume that the PI value is unique to each patient; and each unique PI has a corresponding SS, PI, LL, TK, SFHD and SFVD values. Only PI and SS, SS and LL, LL and TK achieve a concordant match between each other; the body’s gravity line is able to be in the reasonable range of positions and acquire the most economical standing posture. In this respect, Duval-Beaupère and Legaye obtained a prediction equation that can predict a reasonable SS value according to the PI value and predicted a reasonable LL value by SS. Individual parameter evaluation of patients can be conducted by this prediction equation; however, the evaluation using simple mean value of general population is not advisable [4, 9, 11, 15]. As indicated in Fig. 3, among all spinal–pelvis parameters, SS and SFVD have the strongest correlations, which are negative, with the Oswestry score (SS correlation coefficient −0.981, strong; SFVD correlation coefficient −0.802, strong). This indicates that the pelvic anterior tilt, as a compensation, more effectively helps the patients get the economical standing posture. However, compensation via a pelvic posterior tilt may make things worse.

As shown in Figs. 2 and 3, the parameter of LL/TK reflects the features of the spine curve, PT/SS indicates the degree of pelvic tilt, and SFHD/SFVD represents the relative spatial relationship of sacrum and hip joint. An increase in these parameters may cause exacerbation of low back pain. The multiple linear regression analysis confirmed that these parameters were more significantly correlated with the symptoms of low back pain compared with the single parameters, among which PT/SS influenced the most, while LL/TK the least. The ratio between parameters of PT/SS and SFHD/SFVD can also reflect the severity of lumbosacral kyphosis in patients with severe spondylolisthesis, with bigger parameters indicating more severe lumbosacral kyphosis and more severe lumbar pain. Tanguay [22] demonstrated that there was a significant correlation between the lumbosacral kyphosis and quality of life of adolescent patients with severe spondylolisthesis and that regular evaluations of lumbosacral kyphosis should be conducted in adolescent patients with severe spondylolisthesis. This finding is of potential clinical significance. Studies performed by Bourghli et al. [23] and Park et al. [6] all confirmed that PT and SS, as well as the imbalance state of the full-spine curve, were improved after surgery for patients with spondylolisthesis. The changes of patient’s spinopelvic parameters before and after operation and the proper ratio of parameters and the balance state of the spine curve should be taken into account when selecting the therapeutic schedule and operation methods. It is far from enough to simply make a local reduction on spondylolisthesis. As shown in Fig. 4, a

Fig. 3 a–b PT/SS indicates the degree of pelvic tilt, and c–d SFHD/SFVD represents the relative spatial relationship of sacrum and hip joint

Fig. 4 a Lateral radiograph of the spine prior to surgery, “decompensation” spine curve. b Spinopelvic parameters of lateral radiograph changed after surgery; c lateral radiograph of the spine 2 years after operation, “compensation” spine curve

reduction in spondylolisthesis is achieved after operation, and the full-spine curve changes from “decompensation” to “compensation”. In addition, the parameters of PT/SS, LL/TK, and SFHD/SFVD were all improved, the lumbosacral kyphosis and the while spinal curve unbalance of patient were well corrected, and the patient was satisfied with the clinical outcome in terms of sagittal plane morphology.

Labelle et al., Mac-Thiong, and Spinal Deformity Study Group (SDSG) [19–21] proposed a classification method for spondylolisthesis, which is of great importance. On this

basis, specific PT/SS and SFHD/SFVD ratios can be added to classify spondylolisthesis in detail. During preoperative assessment, the ideal parameters should be calculated to match PI through the parameter predication equation; and whether the ratio between parameters is concordant should be determined [4, 9, 11, 15]. In our opinion, the following three factors are critical to the decision to proceed with surgery: (1) ratios of PT/SS, and SFHD/SFVD; (2) ratio of LL/TK and value of SC7D; and (3) age. As shown in Fig. 5, for patients with larger ratios of PT/SS and SFVD/

Fig. 5 Flowchart: determination of an indication for surgery based on the patient's spinopelvic parameters and age

SFHD, as well as larger LL/TK ratio and SC7D, surgeries are indicated in spite of age. While for patients with smaller ratios of PT/SS and SFVD/SFHD, as well as smaller LL/TK ratio and SC7D, conservative treatment can be adopted regardless of the age. For patients with obviously larger ratios of PT/SS and SFVD/SFHD, but almost normal LL/TK ratio and SC7D, and patients with smaller ratios of PT/SS and SFVD/SFHD, but larger LL/TK ratio and SC7D, we are inclined to conduct surgeries in adolescent patients, since it is easier for adolescent patients to develop lumbosacral kyphosis, unbalance of trunk, and regression of adjacent segments with age.

Comparing the correlation between PT/SS, SFHD/SFVD, LL/TK and the clinical symptoms, our findings demonstrate that the ratio of PT/SS had the greatest correlation with clinical symptoms in patients. Thus, we propose that to determine the standard PT/SS ratio for the purpose of classification of different unbalance types, we can: (1) Compare the difference of PT/SS in the normal population and in patients with severe spondylolisthesis whose PI values are similar, but whose clinical symptoms are visibly different. (2) Conduct long-term follow-up on patients with severe spondylolisthesis under conservative treatment to determine the PT/SS features of patients with less variable clinical symptoms. (3) Evaluate a possible correlation between the PT/SS ratio and post-operative outcomes. Further investigation, described above, will help develop a more reliable and detailed systematic rating scale containing ratios of PT/SS, SFHD/SFVD, and LL/TK, values of PI, and SC7D, spondylolisthesis percentage, age, and clinical symptoms. The scale will serve to guide the decision to proceed with surgery and to orient further studies.

Conclusions

The results of this study show that the change of spinopelvic parameters has a significant correlation with the signs and symptoms of spondylolisthesis. Spondylolisthesis grade, PT, LL, SC7D, and SFHD were shown to have a

significant positive correlation with low back pain, while SS and SFVD were shown to have a significant negative correlation. However, in spite of being an important symptom of spondylolisthesis, PI is not significantly correlated with the clinical symptoms for patients with severe spondylolisthesis. Furthermore, the parameters of PT/SS, SFHD/SFVD and LL/TK were significantly correlated with the symptoms of low back pain compared with the single parameters, and may result in exacerbation of the clinical symptoms of low back pain.

Conflict of interest None.

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