Influence of Lumbar Curvature and Rotation on Forward Flexibility in Idiopathic Scoliosis

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Background: Lumbar spine facet joints are arranged sagittally and mainly provide forward flexibility. Rotation of the lumbar vertebral body and coronal plane deformity may influence the function of lumbar forward flexibility. We hypothesize that the more advanced axial and coronal plane deformity could cause more limitation on forward flexibility in patients with idiopathic scoliosis.

Methods: Between January 2011 and August 2011, 85 patients with adolescent idiopathic scoliosis were enrolled in this study. The proximal thoracic, major thoracic, thoracolumbar/lumbar (TL/L), and lumbar (L1/L5) curves were measured by Cobb's method. Lumbar apical rotation was graded using the Nash–Moe score. Lumbar forward flexibility was measured using the sit and reach (S and R) test. Statistical analysis was performed using one-way analysis of variance (ANOVA), Spearman's and Pearson's correlation coefficients.

Results: The mean age was 16.1 ± 2.84 years. The mean proximal thoracic, major thoracic, TL/L, and L1/L5 curves were 17.61° ± 8.92, 25.56 ± 11.61, 26.09° ± 8.6, and 15.10° ± 7.85, respectively. The mean S and R measurement was 25.56 ± 12.33 cm. The magnitude of the TL/L and L1/L5 curves was statistically positively related to vertebral rotation ($r_s = 0.580$ and 0.649, respectively). The correlation between the S and R test and both the TL/L and L1/L5 curves was negative ($r_p = -0.371$ and -0.595, respectively). Besides, the S and R test also demonstrated a significant negative relationship with vertebral rotation ($r_s = -0.768$).

Conclusion: In patients with idiopathic scoliosis, spinal deformity can diminish lumbar forward flexibility. Higher lumbar curvature and rotation lead to greater restriction of lumbar flexion.

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Key words: facet joint, lumbar spine, scoliosis, sit and reach test, vertebral rotation

At a Glance Commentary

Scientific background of the subject

Lumbar spine facet joints are arranged sagittally and mainly provide forward flexibility. Rotation of the lumbar vertebral body and coronal plane deformity influence the function of lumbar forward flexibility.

What this study adds to the field

In patients with idiopathic scoliosis, spinal deformity can diminish lumbar forward flexibility. The magnitude of the lumbar curve was statistically positively related to vertebral rotation. Higher lumbar curvature and rotation lead to greater restriction of lumbar flexion.

The spine is capable of ventroflexion, extension, lateral flexion, and rotation. The degree and combination of the individual types of motion vary considerably in the different vertebral regions, and are determined by the size, shape, and plane of the neighboring articulation. In the lumbar spine, the facet joints lie in a ventromedial to dorsolateral plane.[1,2] The alignment of facet joints is thought to be anatomically designed to allow sagittal and frontal plane rotation. Anterior translation and axial rotation are limited considerably.

The main deformities in patients with idiopathic scoliosis are axial vertebral rotation, deformity in the coronal plane, and hypokyphosis. Since numerous hypothesis were introduced to explain the spine deformity of scoliosis, such as asymmetric vertical growth induced by unbalanced

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load[3] and asymmetric growth of pedicles,[4] no single cause of idiopathic scoliosis can be identified. The facets of the lumbar spine are set mainly in the sagittal plane and their articulation lies in a ventromedial to dorsolateral plane.[5] Because of the presence of axial rotation and coronal plane curvature, the sagittally arranged facet joints may not be able to align in a row in order to provide good forward flexion. Thus, we hypothesized that patients with greater lumbar curvature or lumbar rotation would present with less lumbar flexion in the sagittal plane.

METHODS

Inclusion criteria and curve evaluation

We enrolled patients with idiopathic adolescent scoliosis from our outpatient clinic between January and August 2011. The basic inclusion criterion was a major curve of more than 20°. Patients with neuromuscular disease and congenital scoliosis were excluded. General demographic data were recorded. Plain radiography including the entire spine posterior–anterior view and the entire spine lateral view was obtained. We measured the proximal thoracic, major thoracic, and thoracolumbar/lumbar (TL/L) curves using the Cobb method. The coronal curve angle of L1-L5 was also measured over the superior end plate of L1 and inferior end plate of L5 (L1/L5 curve). The most highly rotated segment of the lumbar spine, either in structure or compensatory curve, was graded using the Nash–Moe score.[6]

Forward flexibility measurement

Meanwhile, lumbar forward flexibility was measured using the sit and reach (S and R) test (Sinwanai, Taipei, Taiwan) [Figure 1]. When testing lumbar forward flexibility, patients were asked to sit on the floor with legs out straight ahead. Feet with shoes off were placed with the soles flat against the test device and shoulder-width apart. Both knees were held flat against the floor. With hands on top of each other and palms facing down, the patient reached forward along the measuring line as far as possible. The measuring stick on the device has the zero mark at 25 cm before the feet. The result was recorded directly from the meter on the device.

Grouping and statistics

Patients were divided into groups according to their Nash–Moe apical score (score 0, 1, 2, 3, and 4). Statistical analysis was performed using IBM SPSS 19.0. Descriptive statistics were carried out for all measurements. Differences in the L1/L5 curve angle, TL/L curve angle, and S and R test measurements among groups were identified using one-way analysis of variance (ANOVA). The significance of differences between each group was examined by Scheffe's test. A significant difference was defined as $p < 0.05$. The correlation between the L1/L5 curve angle or TL/L curve angle and the S and R test was assessed using the Pearson correlation coefficient since they are all interval scales. On the other hand, the correlation between the L1/L5 curve angle or TL/L curve angle and the vertebral rotation was analyzed using the Spearman's correlation coefficient since the vertebral rotation was ranked by Nash–Moe rotation score which is an ordinal scale. Correlation coefficients of 0.0-0.24, 0.25-0.49, 0.50-0.75, and 0.76-1.0 were considered as absent to poor, poor to moderate, moderate to good, and good to excellent, respectively.[7]

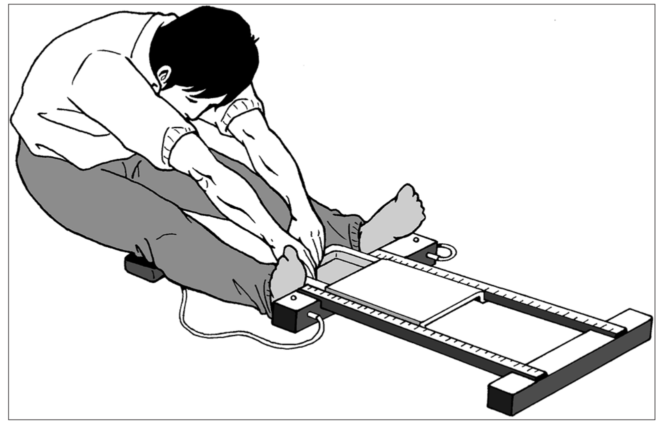

Figure 1: The photo illustrates the S and R test device for measuring lumbar forward flexibility

RESULTS

Patient data

General demographic data are shown in Table 1. There were 17 males and 68 females enrolled in the study, and the mean age was 16.1 ± 2.84 years. There were 6, 2, 7, 17, and 53 patients with Risser sign 0, 1, 3, 4, and 5, respectively. The mean proximal thoracic curve, major thoracic curve, and TL/L curve measured by Cobb's method was 17.61° ± 8.92 , 25.56° ± 11.61 , and 26.09° ± 8.6 , respectively. The mean L1/L5 curve angle was 15.10° ± 7.85 , and the mean S and R measurement was 25.56 ± 12.33 cm. For the lumbar rotation, graded using the Nash–Moe apical score, there were 13, 31, 29, and 12 patients graded with score 0, 1, 2, and 3, respectively. None of our enrolled patients was graded as score 4.

Vertebral rotation

Patients were divided into groups based on the Nash–Moe rotation score. The TL/L curve angles of the Nash–Moe apical score 0, 1, 2, and 3 groups were 18.7° ± 5.0 , 23.5° ± 8.7 , 28.5° ± 5.2 , and 34.5° ± 9.3 , respectively [Table 2]. The difference determined by one-way ANOVA test showed a significant result ($p < 0.001$). The results of multiple comparisons by Scheffe's test demonstrated significantly larger TL/L curve angles of Nash–Moe score 3 group than score 0 and 1 groups. It also showed significantly higher TL/L curve angles of Nash–Moe score 2 group than score 0 and 1 groups. Figure 2A reveals the results of multiple comparisons. Accordingly, the TL/L curve magnitude was statistically positively related to the extent of vertebral rotation (r_s = 0.580). The average L1/L5 curve angles were 6.9° ± 5.2°, 12.7° ± 6.4°, 18.1° ± 5.0°, and 22.9° ± 9.1° in groups 0, 1, 2, and 3, respectively. The results of multiple comparisons by Scheffe's test demonstrated significantly larger L1/L5 curve angles of Nash–Moe score 3 group than score 0 and 1 groups. It also showed significantly larger TL/L curve angles of Nash–Moe score 2 group than score 0 group. For the L1/L5 curve, this also showed a statistically positive correlation with apical vertebral rotation (r_s = 0.649). Figure 2B shows significant differences (*) of Scheffe's test between groups.

Table 1: General demographic data

Male:Female	17: 68
Mean age	16.1±2.84 (years)
Average proximal thoracic curve	17.61°±8.92°
Average major thoracic curve	25.56°±11.61°
Average TL/L curve	26.09°±8.6°
Average L1/L5 curve	15.10°±7.85°
Mean S and R test	25.56±12.33 (cm)
Nash-Moe rotation score (grade, number)	0:1:2:3=13:26:29:12

Abbreviations: TL/L:Thoracolumbar/lumbar; L: Lumbar

Table 2: ANOVA test shows significant difference of TL/L curve, L1/L5 curve, and S and R test between each group graded by Nash-Moe score

	Nash-Moe apical rotation score				ANOVA
	0 Mean±SD	1 Mean±SD	2 Mean±SD	3 Mean±SD	*p*
TL/L curve	18.7±5.0	23.5±8.7	28.5±5.2	34.5±9.3	<0.001†
L1/L5 curve	6.9±5.2	12.7±6.4	18.1±5.0	22.9±9.1	<0.001†
S and R test	42.2±4.6	29.7±7.8	19.6±9.3	11.4±8.1	<0.001†

Abbreviations: †: Statistically significant difference; TL/L: Thoracolumbar/lumbar; L: Lumbar; ANOVA: Analysis of variance; SD: Standard deviation

Sit and reach test

The S and R test measurements for the patients whose Nash–Moe score was 0, 1, 2, and 3 were 42.2 ± 4.6, 29.7 ± 7.8, 19.6 ± 9.3, and 11.4 ± 8.1 cm, respectively. The significance of differences between each group, determined by one-way ANOVA, revealed that patients with greater lumbar vertebral body rotation had statistically significantly lower lumbar forward flexibility. Figure 2C shows the means and 95% Confidence Intervals, and the results of multiple comparisons by Scheffe's test revealed significantly higher S and R test of Nash–Moe score 0 group than score 1 group, score 1 group than score 2 group, and score 2 group than score 3 group, respectively. This result demonstrated significant negative correlation between vertebral rotation and S and R test (r_s = 0.768).

The correlation between the TL/L curve angle and the S and R test measurements was statistically significant and the correlation coefficient r_p was 0.371. This revealed that the S and R test was poorly to moderately negatively correlated with TL/L curve angle [Figure 3]. On the basis of the coefficient of determination value (R^2 = 0.156), the TL/L curve degree explained approximately only 15.6% of lumbar flexibility evaluated using the S and R test. On the other hand, the correlation coefficient r_p between the L1/L5 curve angle and the S and R test was 0.595 ($p < 0.005$) and the R^2 value was 0.354 [Figure 3]. The S and R test showed moderate to good negative correlation with the TL/L curve angle, and showed greater correlation than with the L1/L5 curve angle. The R^2 value demonstrated that the L1/L5 curve angle could influence 35.4% of lumbar flexibility evaluated using the S and R test.

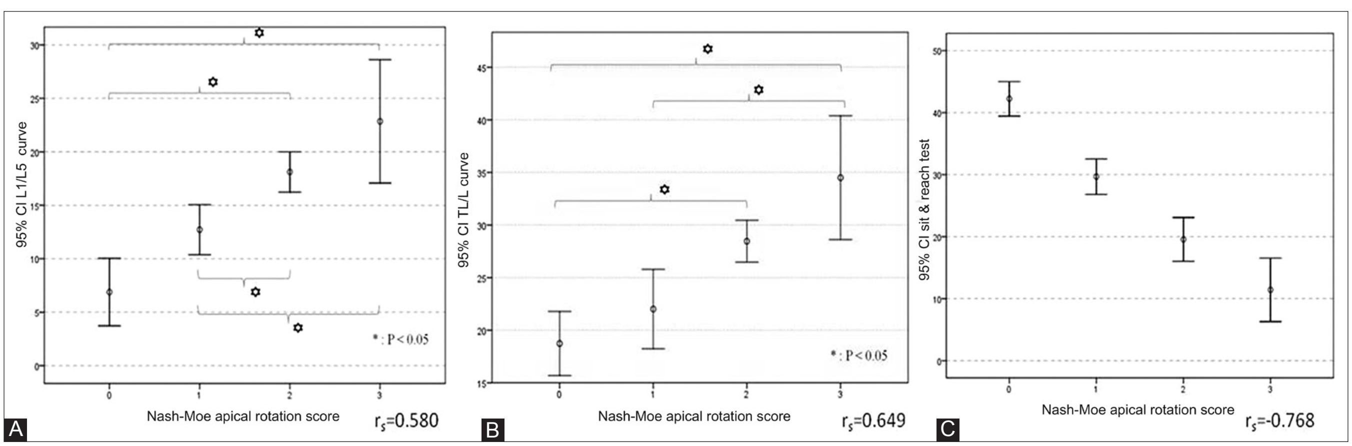

Figure 2: (A) The TL/L curve magnitude positively relates to the extent of vertebral rotation and shows significant differences (*) between each group. (B) The L1/L5 curve angle shows a statistically positive relation to the degree of vertebral rotation. (C) Patients with greater lumbar vertebral body rotation have significantly lower lumbar forward flexibility. Statistical difference is demonstrated between each group

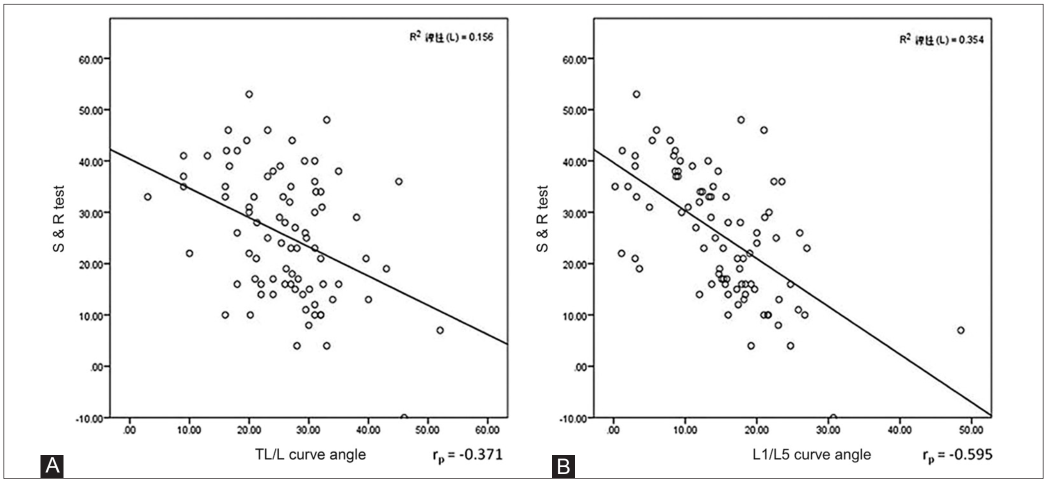

Figure 3: The S and R test negatively correlates with the TL/L curve angle (A) and rp = 0.371, representing poor to moderate negative correlation. Also, the S and R test negatively correlates with L1/L5 curve angle (B) and rp = 0.595, representing moderate to good negative correlation

DISCUSSION

Idiopathic scoliosis is regarded as a multifactorial disease. Asymmetrical growth of the vertebrae on the concave and convex side, due to asymmetric loading, has been considered to be part of the pathogenesis of it.[3] Wang *et al*. revealed, in a histomorphological study, the difference in histological grades and cellular activity between the convex and concave sides, which indicates the different growth kinetics.[8] In addition to asymmetric vertical growth, the asymmetric growth of the neurocentral junction is thought to produce pedicle asymmetry, which further induces vertebral rotation and, consequently, lateral curvature in idiopathic scoliosis.[4] The disturbed equilibrium in the anterior and posterior column growth has been hypothesized to produce hypokyphosis or lordosis of the thoracic spine by relative anterior spinal overgrowth.[9-11] This phenomenon was addressed by Lawton and Dickson[12] and Smith and Dickson[13] who produced experimental scoliosis by posterior tethering and lateral release and simulated the overgrowth of anterior column.

Deformity in a scoliotic spine involves coronal, sagittal, and transverse planes. Deformity in all three planes does not develop in isolation, but is dependent on both type and severity. A positive correlation between axial rotation and coronal deformity was demonstrated in a radiographic evaluation with a standard spine anteroposterior view, lateral view, and Perdriolle torsionmeter.[14] Gocen and Havitcioglu[15] evaluated the correlation of coronal plane deformity and rotation degree by anteroposterior radiography and computed tomography. Their results demonstrated significant correlation between rotation degree and coronal deformity in patients with curvature of more than 30°. Furthermore, consistent positive correlation between coronal plane deformity and axial rotation has been observed and defined as being a typical feature of scoliosis, and is referred to as a coupling mechanism.[2,16] In our study, the results demonstrated a positive trend showing that a larger TL/L curve angle is accompanied by greater axial rotation.

The shape, position, and spatial orientation of facet joints have been shown to be main factors that determine spinal biomechanical and motion contributions. The facets of the lumbar spine are set mainly in the sagittal plane and their articulation lies in a ventromedial to dorsolateral plane.[5] In a cadaveric study, which screened three-dimensional human vertebral columns, the results revealed that the lumbar facet showed the greatest sagittal orientation in L2 (approximately 25°) and increased gradually to L5.[1] Thus, lumbar segments are able to provide superior flexibility over the sagittal plane. Because spinal motion relies mainly on the geometrical property of the facet joints, the modification of the angular orientation of facet joints could result in a change in the normal biomechanical role of vertebrae and the surrounding structure.[2,17] In the present study, we have demonstrated a significant difference in S and R measurements between each group possessing a different degree of spine rotation. The group with more severe spine rotation had lower results in the S and R test, representing the spine forward flexibility in our study. A high degree of lumbar axial rotation, as graded by the Nash–Moe score, is accompanied by poor lumbar flexion, as estimated by the S and R test. Hence, the disarrangement of facets over the transverse plane would reduce spinal forward flexibility. To show the influence of coronal plane deformity on lumbar forward flexibility, we investigated the correlation between the curve angle and the S and R test measurement. Figure 3a reveals the relationship of the TL/L curve angle and the S and R test. The Pearson's correlation coefficient r_p = 0.371 indicates the negative relationship between TL/L curve angle and the S and R test with poor to moderate correlation. Because the major flexion/extension range of motion is located on the L1/L5 segments,[2] we also examined the correlation between the L1/L5 curve and the S and R test. The Pearson's correlation coefficient $r_p = 0.595$ also represented moderate to good negative correlation. We believe that the negative correlation between the S and R test and the L1/L5 curve is more significant than between the S and R test and the TL/L curve. The end vertebra of the curve is the one that tilts the most into the concavity of the curve being measured in Cobb's method. Therefore, the TL/L curve may include any segment of the thoracolumbar spine. On the other hand, the L1/L5 curve is defined as the curve between the L1 and L5 segments, which provides the main flexion and extension. The effect of coronal plane facet disarrangement on lumbar flexibility would be more apparent in this region. Therefore, the correlation coefficient between the S and R test and the L1/L5 curve is greater than with the TL/L curve.

The S and R test was first described in 1952 by Wells and Dillon for measuring hamstring and lower back flexibility.[18] They compared the scores in the S and R test to the scores in the standing and bobbing test in college-age women and found high validity, with $r = 0.9$. On the contrary, Jackson and Langford reported the validity coefficients of the S and R test to be only $r = 0.59$ for low back flexibility.[19] While some suggested that limb length differences might interfere with the validity of S and R test,[20] others advocated that there was no significant relationship between S and R test performance, leg length, and the standing reach test.[21] In addition to these variables, which can affect the validity of the S and R test, we found that a regular exercise habit can give rise to better results in the S and R test. In our study, two patients, a ballet dancer and a gymnast, showed excellent flexibility in the S and R test (47 and 48 cm, respectively), despite considerable lumbar curvature of 50° and 54°, respectively. This could have resulted from their supple lower lumbar spine and hamstring and implies that improvement of lumbar flexibility could be achieved by regular exercise. Due to these multiple variables, the negative correlation between TL/L curve and the S and R test is poor to moderate ($r_p = 0.371$) in our study. The correlation was increased by selecting curve measurements on the L1/L5 section of the spine, which showed moderate to good correlation ($r_p = -0.595$).

The results of our study could be more validated by improving the measurement of lumbar forward flexibility and alignment of facet joint articulation. The axial rotation of vertebra could be more accurately evaluated with computer tomography.[22] The lumbar flexibility could be calculated by the angle change of dynamic lateral flexion–extension views. However, excessive radioactive exposure is a big concern for these patients who are still in their rapid growth status. Thus, the S and R test was chosen as our modus for carrying out patient evaluation.

CONCLUSION

In patients with idiopathic scoliosis, the disarrangement of facet joints over the coronal and transverse planes could diminish lumbar flexibility over the sagittal plane. Greater lumbar curvature and rotation leads to a greater restriction of lumbar flexion.

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