DEFORMITY

Association Between Radiographic Spinopelvic Parameters and Health-related Quality of Life in De Novo Degenerative Lumbar Scoliosis and Concomitant Lumbar Spinal Stenosis

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Study Design. A retrospective clinical study of patients who were treated from January 2011 to December 2018 and met our criteria.

Objective. The aim of this study to investigate the relationship between radiographic spinopelvic parameters and the health-related quality of life (HRQOL) in pretreatment de novo degenerative lumbar scoliosis (DNDLS) patients with concomitant lumbar spinal stenosis (LSS).

Summary of Background Data. DNDLS has garnered attention because of the increasing aged population. Unlike other types of spine deformities, DNDLS may occur with concomitant LSS. Radiographic spinopelvic parameters are important for evaluating spine alignment in these patients; however, the association between these parameters and the HRQOL is unknown.

Methods. Data from 204 patients diagnosed with DNDLS and concomitant LSS were reviewed. HRQOL was assessed using the visual analog scale (VAS) scores (for the back and leg), Oswestry Disability Index (ODI), Japanese Orthopaedic Association (JOA) scores, and Scoliosis Research Society (SRS)-22 questionnaire (SRS-22). Radiographic spinopelvic parameters were obtained from anteroposterior and lateral x-rays. The relationship between spinopelvic parameters and HRQOL was analyzed by correlation analysis in the overall population.

Results. Lumbar lordosis (LL) showed clinical relevance to JOA ($r = 0.290$), ODI ($r = -0.269$), SRS-22 pain domain ($r = 0.134$), SRS-22 function domain ($r = 0.257$), and VAS for back pain ($r = -0.196$). There was clinical relevance between T1 pelvic angle (T1PA) and JOA ($r = -0.212$) and ODI ($r = 0.251$), sagittal vertical axis (SVA) and JOA ($r = -0.211$) and SRS-22 function domain ($r = -0.229$) and ODI ($r = 0.215$), and L1 pelvic angle (L1PA) and ODI ($r = 0.200$). HRQOL differences were validated in the SVA and PI-LL groups by SRS-Schwab classification. A significant difference was validated by setting a sagittal balance threshold for SVA, T1PA, T1 sagittal tilt, and L1PA.

Conclusion. The sagittal radiographic parameters showed a weak correlation with preoperative HRQOL in patients with concomitant DNDLS and LSS. T1PA, T1ST, and L1PA can effectively assess pretreatment HRQOL.

Key words: de novo degenerative lumbar scoliosis, degenerative segment disease, health related quality of life, lumbar pelvic angle, spinopelvic parameter, T1 pelvic angle.

Level of Evidence: 4

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De novo degenerative lumbar scoliosis (DNDLS) is a subtype of adult spinal deformity (ASD), arising from asymmetrical degenerative disc or facet joint arthritis. The incidence of DNDLS is reported as 8.85% to 19.2%, and 16.1% of DNDLS is combined with concomitant lumbar spinal stenosis (LSS).[1–3]

Radiographic spinopelvic parameters are indispensable tools for the evaluation of spine alignment. The sagittal modifiers (pelvic tilt [PT], pelvic incidence-lumbar lordosis [PI-LL], and sagittal vertical axis [SVA]) were adopted in the Scoliosis Research Society (SRS)-Schwab classification, and sagittal imbalance was defined as SVA ≥5 cm by another

study.[4,5] Additionally, some novel parameters such as T1 pelvic angle (T1PA), L1 pelvic angle (L1PA), and T1 sagittal tilt (T1ST) have attracted recent interest in the evaluation of spine balance status.[6–8]

Although multiple studies have focused on the relationship between spinopelvic parameters and health-related quality of life (HRQOL) in ASD patients, a general consensus has not been reached.[7,9,10] We speculated that the possible cause of the controversy was inclusion of the various subtypes of ASD in these previous studies. Thus, we have limited this study to pretreatment DNDLS with concomitant LSS patients; we also investigated the association between spinopelvic parameters and the HRQOL in these patients.

MATERIALS AND METHODS

Inclusion Criteria
Our hospital's electronic database was retrospectively reviewed. Patients diagnosed with DNDLS from January 2011 to December 2018 who met the following criteria were included: age >50 years; presence of DNDLS with Cobb angle >10°; apical vertebra in the lumbar region; concomitant LSS; and availability of complete radiographs.

Exclusion Criteria
The exclusion criteria were: a history of juvenile or adolescent idiopathic scoliosis; spine deformity caused by infection, trauma, or tumor; neuromuscular spinal abnormalities; previous spine surgery or hip arthroplasty history; or radiographic examination shows double curves of scoliosis.

HRQOL Measurements
The quality of life was evaluated by HRQOL questionnaires, which included the visual analog scale (VAS) scores for the back and leg, Oswestry Disability Index (ODI), and the Japanese Orthopaedic Association (JOA) scoring system. SRS-22 questionnaire (SRS-22) was also administered for self-assessment of quality of life.

All HRQOL values were extracted from our electronic medical database, which recorded the original electronic medical document.

Radiographic Parameter Measures and Classification
The complete standing long-cassette anteroposterior and lateral spine radiographs were obtained. Cobb angle, apex vertebra, upper and lower ending vertebra were evaluated from radiographs. The spinopelvic parameters including coronal vertical axis (CVA), SVA, PI, PT, sacral slope (SS), LL, thoracolumbar kyphosis (TK), T1PA, T1ST, and L1PA were obtained from anteroposterior and lateral X-rays. All parameters were measured separately by two expert spine surgeons. T1PA was defined as the angle between the line from the femoral head axis to the centroid of T1, and the line from the femoral head axis to the middle of the superior end plate of S1 e (Figure 1).[6] T1ST was
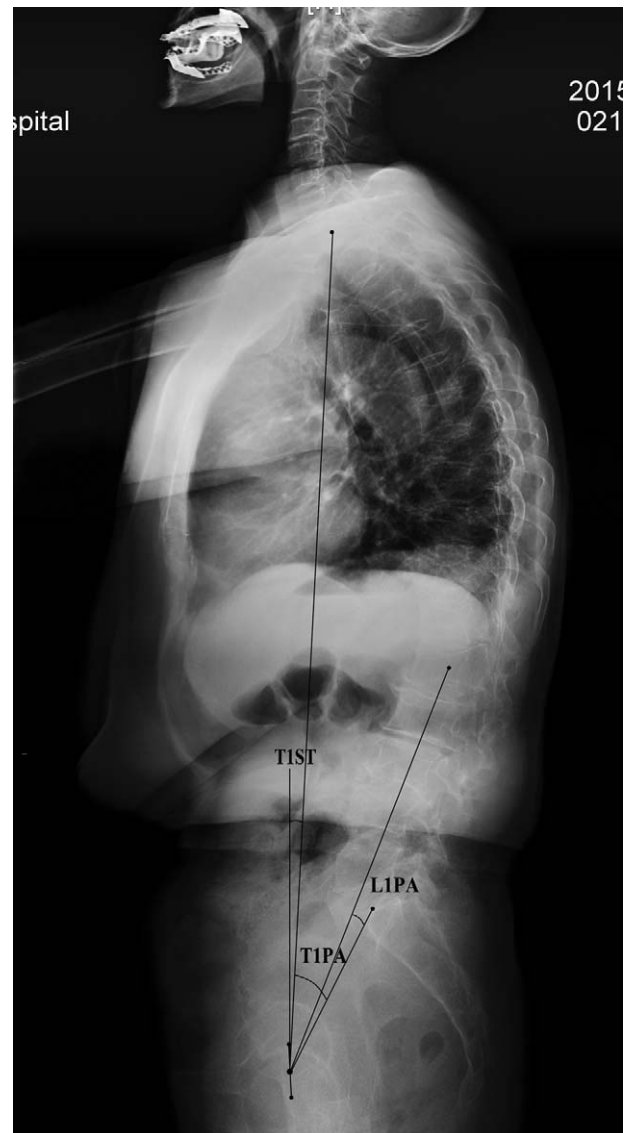
Figure 1. Illustration of T1PA, L1PA, and T1ST. L1PA, L1 pelvic angle; T1PA, T1 pelvic angle; T1ST, T1 sagittal tilt.

defined as the angle between a line drawn from the center of the femoral head axis to the midpoint of the T1 vertebral body and a vertical line (Figure 1).[7] L1PA was defined as the angle formed by a line from the center of the L1 vertebral body to the femoral head axis, and a line from the femoral head axis to the center of the S1 endplate (Figure 1).[8] The radiographs were also collected from the electronic database. All radiographic parameters were measured separately by two expert spine surgeons using the Picture Archiving and Communication System (PACS system, GE, Waukeshau, WI).

The patients were grouped by the sagittal modifiers (PT, PI-LL, and SVA) as neutral (0), positive (+), and very positive (++) according to the SRS-Schwab classification, respectively.

HRQOL data were also divided into subgroups by spinopelvic parameters representing the sagittal alignment

status as follows: T1ST<0° (nonpathologic) or T1ST ≥0° (deformity); T1PA≤20° or T1PA >20°; L1PA <7.2° or L1PA ≥7.2°; and SVA <50 mm (balanced) or SVA ≥50 mm (unbalanced).

Statistical Analysis

Clinical and radiographic data were analyzed using the Statistical Package for the Social Sciences version 22.0 (SPSS, Inc., Chicago, IL). The inter-rater reliability of the classification was tested by using interclass correlation coefficients (ICCs). The clinical relevance between the JOA scores and different parameters (age, SVA, PI, SS, LL, and TK) was analyzed by Pearson analysis. Spearman analysis was utilized to explore the correlation between the JOA scores and other parameters (Cobb angle, CVA, PT, T1PA and L1PA). The clinical relevance between other HRQOL and parameters was analyzed by Spearman correlation. The rank sum test was utilized to compare HRQOL in each subgroup by setting the thresholds of spinopelvic parameters. *P* values <0.05 were considered statistically significant.

RESULTS

Patient Characteristics

Between January 2011 and December 2018, 204 patients (138 men, 66 women) with a mean age of 63.3 ± 6.9 (range, 51–80) years were enrolled in this study.

Among this population, the apical vertebra was at L1, L1/2, L2, L2/3, L3, L3/4, and L4 in 3, 15, 21, 55, 48, 48, and 14 cases, respectively.

The distribution of each radiographic parameter is presented in Table 1.

HRQOL questionnaires were recorded as follows: mean VAS scores for back and leg pain were 5.1 ± 1.9 (range, 0–8) and 5.3 ± 1.8 (range, 0–10), respectively. The mean JOA score and ODI were 14.5 ± 4.5 (range, 4–24) and 25.5 ± 8.7% (range, 12%–46%), respectively. The mean pain, function, self-image, and mental health domain of the SRS-22 were 2.5 ± 0.8 (range, 0.8–4.0), 2.4 ± 0.9 (range,

1.2–4.4), 3.7 ± 0.3 (2.4–4.4), and 3.9 ± 0.5 (2.6–4.5), respectively.

Association Between HRQOL and Other Parameters

With respect to HRQOL, the SVA, T1PA, and LL were correlated to pre-treatment JOA scores (Table 2). *r* values <0.2 was defined as very weak correlation, whereas values between 0.2 and 0.39, 0.4 and 0.59, and 0.6 and 0.79 were defined as weak, moderate, and strong correlation, respectively. The association between ODI and the SVA, T1PA, L1PA, and LL parameters was also validated by Spearman analysis (Table 2). SVA was also correlated with the SRS-2 function domain (Table 3). The higher VAS score for the back and lower SRS-22 pain domain were correlated with lower LL (Table 2, Table 3). However, the clinical relevance between HRQOL and other parameters was not found (Table 2, Table 3).

HRQOL Difference Between Sagittal Modifiers of SRS-Schwab Classification

Table 4 demonstrates *P* values in each SRS-Schwab classification. A statistical significance of the JOA score was detected in the SVA sub-group with differences in the SVA (0) and SVA (++) groups (*P* = 0.015). The ODI was statistically significant in the PI-LL sub-group with differences in the PI-LL (0)-PI-LL (++) (*P* = 0.001) and PI-LL (+)-PI-LL (++) (*P* = 0.001). The statistical significance of JOA scores was also observed in the sub-group with differences in the PI-LL subgroup (0)-PT (++) (*P* = 0.001) and PI-LL (+)-PI-LL (++) (*P* = 0.001).

HRQOL Differences Between Spinopelvic Parameters of Sagittal Balance Status

The results of rank sum test are shown in Table 4. Statistical significance of JOA scores was observed between the SVA (*P* = 0.001), T1PA (*P* = 0.018), and T1ST (*P* = 0.005) groups. The difference in the ODI was also validated in the T1PA (*P* = 0.001) and L1PA (*P* = 0.033) groups (Figure 2).

TABLE 1. The Values and Inter Observer Reliability for Radiographic Parameter

Parameters	Mean	Standard deviation	Range	Inter-rater ICC
SVA, mm	38.2	38.3	−67.0 to 139.2	0.94
CVA, mm	16.3	11.8	1.86 to 70.39	0.92
TK (°)	23.7	10.9	2.4 to 54.1	0.92
LL (°)	36.9	15.6	1.8 to 79	0.91
T1PA (°)	17.6	9.0	1.0 to 46.2	0.88
L1PA (°)	10.2	7.1	−1.8 to 39.4	0.87
T1ST (°)	−2.3	4.8	−11.5 to 29.7	0.85
PI (°)	50.7	1.8	25.9 to 79.1	0.88
SS (°)	30.4	9.9	6.2 to 60.7	0.91
PT (°)	19.9	9.0	3.8 to 46.9	0.88
Cobb angle (°)	17.1	6.9	10.2 to 49.2	0.82

CVA indicates coronal vertical axis; ICC, interclass correlation coefficient; L1PA, L1 pelvic angle; LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; SVA, sagittal vertical axis; T1PA, T1 pelvic angle; T1ST, T1 sagittal tilt; TK, thoracolumbar kyphosis.

TABLE 2. Correlation Between Parameters and JOA, ODI, and VAS

Parameters	JOA	ODI	VAS for Back	VAS for Leg
Age	0.794	0.619	0.253	0.609
Cobb angle	0.052	0.66 (0.660)	0.156	0.101
SVA	0.002*, r = −0.211	0.002*, r = 0.215	0.289	0.24 (0.240)
CVA	0.237	0.612	0.472	0.120
TK	0.178	0.062	0.122	0.312
LL	0.001*, r = 0.290	<0.001*, r = −0.269	0.005*, r = −0.196	0.631
T1PA	0.002*, r = −0.212	<0.001*, r = 0.251	0.071	0.076
L1PA	0.091	0.001*, r = 0.200	0.352	0.091
T1ST	0.056	0.327	0.160	0.574
PI	0.294	0.924	0.800	0.942
SS	0.06 (0.060)	0.072	0.171	0.909
PT	0.053	0.055	0.241	0.321

CVA indicates coronal vertical axis; L1PA, L1 pelvic angle; LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; SVA, sagittal vertical axis; T1PA, T1 pelvic angle; T1ST, T1 sagittal tilt;= TK, thoracolumbar kyphosis.
*$P < 0.01$.

TABLE 3. Correlation Between Parameters and SRS-22

Parameters	SRS-22 Pain	SRS-22 Function	SRS-22 Self-image	SRS-22 Mental Health
Age	0.254	0.682	0.153	0.212
Cobb angle	0.538	0.452	0.642	0.503
SVA	0.161	0.003**, r = −0.229	0.849	0.113
CVA	0.502	0.380	0.077	0.061
TK	0.702	0.676	0.991	0.387
LL	0.041*, r = 0.134	0.013*, r = 0.257	0.659	0.596
T1PA	0.486	0.096	0.366	0.311
L1PA	0.579	0.997	0.609	0.210
T1ST	0.071	0.310	0.210	0.447
PI	0.338	0.392	0.758	0.612
SS	0.294	0.061	0.746	0.312
PT	0.091	0.396	0.239	0.718

CVA indicates coronal vertical axis; L1PA, L1 pelvic angle; LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; SVA, sagittal vertical axis; T1PA, T1 pelvic angle; T1ST, T1 sagittal tilt;= TK, thoracolumbar kyphosis.
*$p < 0.05$.
**$p < 0.01$.

DISCUSSION

Association Between Spinopelvic Parameters and HRQOL

A prospective multicenter analysis reported that the most clinically relevant and strongly correlated radiographic parameters for the ODI were PT, SVA, and PI-LL.[10] However, Chapman et al reported only weak correlations between sagittal modifiers (SS and SVA) and SRS function. There was no significant association reported between preoperative (Preop) HRQOL and radiographic parameters in Takemoto et al's study.[7,11] Thus, the association between

TABLE 4. Rank Sum Test of Modifiers by SRS-Schwab Classification

Modifier	JOA	ODI	VAS Back	VAS Leg	SRS-22 Pain	SRS-22 Function	SRS-22 Self-image	SRS-22 Mental Health
SVA	0.005*	0.057	0.840	0.053	0.142	0.061	0.112	0.412
PT	0.203	0.089	0.314	0.662	0.161	0.102	0.402	0.311
PI-LL	0.003*	<0.001*	0.061	0.782	0.121	0.301	0.089	0.213

JOA indicates Japanese Orthopaedic Association; ODI, Oswestry Disability Index; PI-LL, pelvic incidence-lumbar lordosis; PT-LL, pelvic tilt-lumbar lordosis; SRS-22, Scoliosis Research Society-22 questionnaire; SVA, sagittal vertical axis.
*$P < 0.01$.
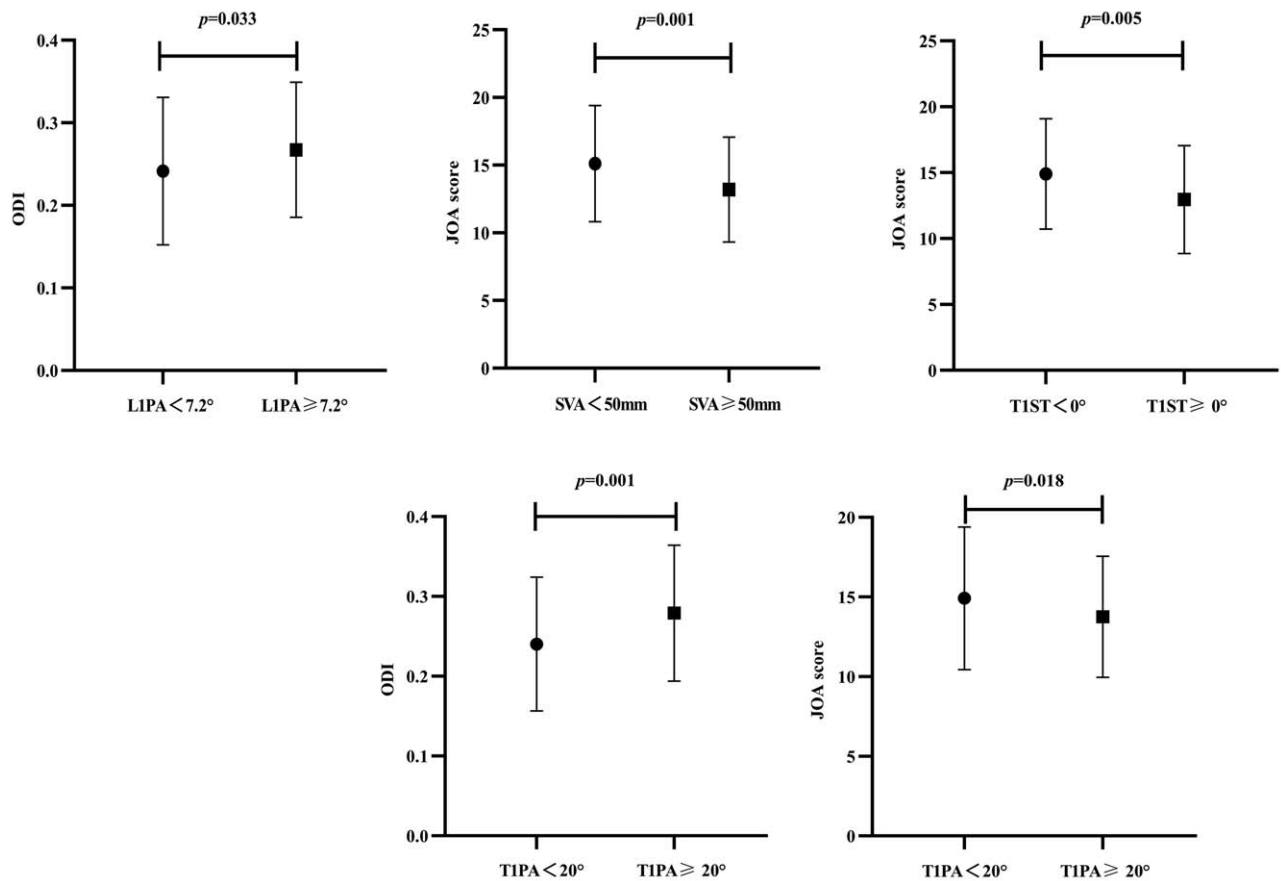
Figure 2. Differences of health-related quality of life between positive spinopelvic parameters. JOA indicates Japanese Orthopaedic Association; L1PA, L1 pelvic angle; ODI, Oswestry Disability Index; SVA, sagittal vertical axis; T1PA, T1 pelvic angle; T1ST, T1 sagittal tilt.

spinopelvic parameters and HRQOL still remained controversial in ASD patients, probably due to the broad spectrum of scoliosis subtypes that were included in these previous studies.

To eliminate the various scoliosis subtypes, Faraj *et al* performed a study composed of 74 DNDLS patients. However, only weak correlations were found between SVA with the ODI ($r = 0.296$) and PT; the numeric rating scale (NRS) for back pain was ($r = -0.260$) and SRS pain domain was ($r = 0.282$).[9] Similarly, very weak correlations between the ODI with T1PA ($r = 0.137$) and PI-LL ($r = 0.137$) were demonstrated in another study.[12] Although the results of a Japanese study suggested weak correlation between LL with lumbar function ($r = 0.285$), and moderate correlation between LL with VAS score for leg pain ($r = 0.328$).[3] In view of the studies mentioned above, weak correlation between HRQOL and radiographic parameters was found in most DNDLS population.

Due to the etiology of DNDLS, concomitant LSS is frequently encountered, and 16.1% of DNDLS is combined with LSS.[3] However, there are few studies on these populations; hence, we collected a large sample size to investigate the relationship between pretreatment HRQOL and radiographic parameters. The weak correlation between these parameters and HRQOL was consistent with previous studies. However, among all the parameters, LL was the most valuable factor that showed clinical relevance for the JOA score ($r = 0.290$), ODI ($r = -0.269$), SRS-22 pain domain ($r = 0.134$), SRS-22 function domain ($r = 0.257$), and VAS score for back pain ($r = -0.196$) in our study. Low back pain patients with lower LL values were also observed in a meta-analysis,[13] which indicated the importance of restoration of a normal lumbar alignment in DNDLS surgery. Correlations between increased sagittal modifier values (SVA and T1PA) and poor HRQOL were also observed. Although an exact compensatory mechanism in DNDLS has not been well documented, it was widely accepted that the plumb line shifted anteriorly under the premise of decreased LL value with aging.[14] Another possible compensatory mechanism was anterior truncal inclination, which resulted in sagittal deformity.[15] Hence, the values of sagittal balance modifier (SVA and T1PA) may be correspondingly increased. We speculated that in patients with DNDLS and concomitant LSS, lumbar malalignment was an initial factor for the decline of HRQOL, and this was followed by malalignment of the global spine. Otherwise, the spinopelvic parameters showed weak correlations to HRQOL. One possible explanation for this might be neural compression caused by concomitant LSS and comorbidity with aging. Therefore, a comprehensive evaluation of global or regional spine alignment, adequate neural decompression, and age-related comorbidity should be considered.

HRQOL and Sagittal Modifiers Graded by SRS-Schwab Classification

No significant difference of HRQOL in all SRS-Schwab classification modifiers (SVA, PT, and PI-LL) was found by Faraj *et al*[12] in DNDLS patients.[9] Conversely, Ha *et al* reported that a significant difference in the ODI was only found between the "Neutral" and "Very Positive" groups. A significant difference in JOA scores was also observed between the "Neutral" and "Very Positive" groups in our study. We postulated that the variety was caused by various Cobb angles. A more severe coronal deformity (a mean Cobb angle 30.7°) was recorded in Faraj *et al*'s study, whereas an average Cobb angle 17.1° to 20.3° was recorded in Ha *et al*'s study and our study.

Although no significant difference of HRQOL in PI-LL modifier was validated in previous study,[9] Ha *et al*[12] reported that a higher ODI was observed in the "Very Positive" PI-LL modifier group than in the "Positive" group. Both the ODI and JOA scores were statistically significant with "Neutral" and "Very Positive" PI-LL modifier groups, and "Positive" and "Very Positive" PI-LL modifier groups. It suggested PI-LL >20° was associated with poorer health status in DNDLS with concomitant LSS patients, and that PI-LL was a more valuable modifier in this condition.

HRQOL Difference in Some Novel Spinopelvic Parameters

In recent years, some novel parameters have emerged and attracted attention due to their ability to evaluate sagittal balance for their convenience.[6–8] SVA, PT, and PI-LL were classical modifiers for evaluating sagittal spine deformity, but could be modified by postural compensation, including pelvic retroversion, knee flexion, and the use of assistive devices for standing. T1PA simultaneously accounts for both spinal inclination and pelvic retroversion and is less affected by variations in standing compensation. Protopsaltis *et al* found strong correlation between T1PA and other classical modifiers (SVA, PT, and PI-LL), and correlations between HRQOL and T1PA were validated in 559 ASD patients.[8] Banno *et al* performed a study composed of 70 ASD patients and grouped them by setting T1PA at a threshold of 20°. No statistical significance between Preop T1PA and HRQOL comparison was found, but a statistical significance was validated after 2-year follow-up.[16] The change between T1PA showed moderate to strong correlations to the changes of HRQOL in adult scoliosis patients.[17] However, the effectiveness of T1PA was still not confirmed in DNDLS patients, and no statistical significance was found in a multicenter analysis.[9] In this study, we found weak correlations between T1PA with the JOA scores and ODI, but the statistical significance of the JOA scores and ODI were confirmed by setting a threshold T1PA value of 20°. This suggests that T1PA was an effective indicator for pretreatment evaluation.

Aiming to facilitate intraoperative measurement, Protopsaltis introduced L1PA for predicting global alignment in ASD patients. This was defined as the lumbar component of the T1PA, and the target value was set <7.2° for an ideal spine alignment. A strong correlation to baseline SVA and T1PA, but weak correlation to baseline HRQOL, was observed in ASD patients. Only a weak correlation to the ODI ($r = 0.200$) was observed in pretreatment patients was consistent with previous studies. Otherwise, differences in HRQOL were compared by setting a threshold of 7.2° to validate its effectiveness. A significant difference in the ODI was also found ($P < 0.01$), which proved its accuracy in this study. Compared with two parameters, T1PA was considered a better factor related to pretreatment health status.

T1ST was firstly described in ASD patients for evaluating the spine balance status; however, its effectiveness with HRQOL is unclear.[18–20] Takemoto considered that T1ST ≥0° indicated sagittal imbalance of the spine, but no significant correlation with HRQOL was found in Preop ASD patients. We first investigated its correlation with HRQOL in DNDLS patients and the result was consistent with Takemoto's study. However, the statistical significance ($P < 0.01$) of JOA scores was validated between T1ST <0° and T1ST ≥0° groups. We speculated that DNDLS was a complicated aging status and global spine alignment, especially sagittal balance should be considered for clinical decision-making.

Limitations

This study has several limitations. First, it was retrospective and conducted at a single center. Second, studies concerning about multiple surgical strategies in DNDLS with concomitant LSS after long-term follow-up was needed to validate role of spinopelvic parameters in such dilemma.

CONCLUSION

The sagittal radiographic parameters showed weak correlation to Preop HRQOL in DNDLS and concomitant LSS patients; hence, other factors should be considered for evaluation. Significant differences in HRQOL were relative to the SVA modifier and the PI-LL modifier groups. T1PA, T1ST, and L1PA also showed effectiveness in assessing Preop HRQOL. We speculated that DNDLS was a complicated aging status and that global spine alignment, especially sagittal balance, should be considered for clinical decision-making.

> ## Key Points

- ❑ DNDLS may occur with concomitant LSS.
- ❑ The association between spinopelvic parameters and HRQOL is unclear.
- ❑ Sagittal radiographic parameters showed a weak correlation with preoperative HRQOL in patients with DNDLS and concomitant LSS.
- ❑ The T1 pelvic angle, T1 sagittal tilt, and L1 pelvic angle can be effectively used to assess preoperative HRQOL.

Acknowledgments

References

1. Xu L, Sun X, Huang S, et al. Degenerative lumbar scoliosis in Chinese Han population: prevalence and relationship to age, gender, bone mineral density, and body mass index. *Eur Spine J* 2013;22:1326–31.

2. Kebaish KM, Neubauer PR, Voros GD, et al. Scoliosis in adults aged forty years and older: prevalence and relationship to age, race, and gender. *Spine (Phila Pa 1976)* 2011;36:731–6.

3. Iizuka Y, Iizuka H, Mieda T, et al. Epidemiology and associated radiographic spinopelvic parameters of symptomatic degenerative lumbar scoliosis: are radiographic spinopelvic parameters associated with the presence of symptoms or decreased quality of life in degenerative lumbar scoliosis?. *Eur Spine J* 2016;25:2514–9.

4. Schwab F, Ungar B, Blondel B, et al. Scoliosis Research Society-Schwab adult spinal deformity classification: a validation study. *Spine* 2012;37:1077–82.

5. Lafage V, Bharucha NJ, Schwab F, et al. Multicenter validation of a formula predicting postoperative spinopelvic alignment. *J Neurosurg Spine* 2012;16:15–21.

6. Protopsaltis T, Schwab F, Bronsard N, et al. The T1 pelvic angle, a novel radiographic measure of global sagittal deformity, accounts for both spinal inclination and pelvic tilt and correlates with health-related quality of life. *J Bone Joint Surg Am* 2014;96:1631–40.

7. Takemoto M, Boissière L, Vital JM, et al. Are sagittal spinopelvic radiographic parameters significantly associated with quality of life of adult spinal deformity patients? Multivariate linear regression analyses for pre-operative and short-term post-operative health-related quality of life. *Eur Spine J* 2016;26:2176–86.

8. Protopsaltis TS, Lafage R, Smith JS, et al. The lumbar pelvic angle, the lumbar component of the T1 pelvic angle, correlates with HRQOL, PI-LL mismatch, and it predicts global alignment. *Spine (Phila Pa 1976)* 2018;43:681–7.

9. Faraj SSA, De Kleuver M, Vila-Casademunt A, et al. Sagittal radiographic parameters demonstrate weak correlations with pretreatment patient-reported health-related quality of life measures in symptomatic de novo degenerative lumbar scoliosis: a European multicenter analysis. *J Neurosurg Spine* 2018;28:573–80.

10. Schwab FJ, Blondel B, Bess S, et al. Radiographical spinopelvic parameters and disability in the setting of adult spinal deformity: a prospective multicenter analysis. *Spine (Phila Pa 1976)* 2013;38:E803–12.

11. Chapman TM, Baldus CR, Lurie JD, et al. Baseline patient-reported outcomes correlate weakly with radiographic parameters: a multicenter, prospective NIH Adult Symptomatic Lumbar Scoliosis Study of 286 patients. *Spine (Phila Pa 1976)* 2016;15:1701–8; 41.

12. Ha KY, Jang WH, Kim YH, et al. Clinical relevance of the SRS-Schwab classification for degenerative lumbar scoliosis. *Spine (Phila Pa 1976)* 2016;41:E282–8.

13. Chun SW, Lim CY, Kim K, et al. The relationships between low back pain and lumbar lordosis: a systematic review and meta-analysis. *Spine J* 2017;17:1180–91.

14. Schwab F, Lafage V, Patel A, et al. Sagittal plane considerations and the pelvis in the adult patient. *Spine (Phila Pa 1976)* 2009;34:1828–33.

15. Buckland AJ, Vira S, Oren JH, et al. When is compensation for lumbar spinal stenosis a clinical sagittal plane deformity?. *Spine J* 2016;16:971–81.

16. Banno T, Hasegawa T, Yamato Y, et al. T1 pelvic angle is a useful parameter for postoperative evaluation in adult spinal deformity patients. *Spine (Phila Pa 1976)* 2016;41:1641–8.

17. Qiao J, Zhu F, Xu LT, et al. pelvic angle: a new predictor for postoperative sagittal balance and clinical outcomes in adult scoliosis. *Spine (Phila Pa 1976)* 2014;39:2103–7.

18. Schwab F, Patel A, Ungar B, et al. Adult spinal deformity-postoperative standing imbalance: how much can you tolerate? An overview of key parameters in assessing alignment and planning corrective surgery. *Spine (Phila Pa 1976)* 2010;35:2224–31.

19. Lafage V, Schwab F, Patel A, et al. Pelvic tilt and truncal inclination: two key radiographic parameters in the setting of adults with spinal deformity. *Spine (Phila Pa 1976)* 2009;34:E599–606.

20. Vialle R, Levassor N, Rillardon L, et al. Radiographic analysis of the sagittal alignment and balance of the spine in asymptomatic subjects. *J Bone Joint Surg Am* 2005;87:260–7.