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Stiffness-Related Disability Following Surgical Correction for Adolescent Idiopathic Scoliosis: A Comparative Analysis According to the Lowest Instrumented Vertebra Level

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Background: Extensive spinal fusion inevitably results in loss of mobility, which may induce stiffness-related disability (SRD) during activities of daily living. Few studies have examined SRD after surgical correction for adolescent idiopathic scoliosis (AIS). This study aimed to investigate SRD following surgical treatment in AIS patients particularly with respect to the lowest instrumented vertebra (LIV).

Methods: Patients who underwent surgical correction for AIS between 2014 and 2021 and were followed up for 2 years were included. The degree of SRD was evaluated using the Stiffness-Related Disability Index (SRDI), which consists of 4 categories, each containing 3 questions, giving a total of 12 components of the questionnaire. The SRDI scores were compared according to the LIV level. Correlation analysis was performed to examine the relationship between the SRDI and legacy health-related quality of life (HRQOL) measurements.

Results: This study included 174 patients (47 men and 127 women) with a mean age of 13.8 years. Among the 12 items of the SRDI, the scores of 9 items showed a significant increase after surgery. The total sum of the SRDI scores also significantly increased after surgery. Pearson correlation analysis showed that the SRDI scores were significantly correlated with Oswestry disability index, nearly all domains, and the total sum of Scoliosis Research Society-22 questionnaire, and 36-Item Short Form Survey. No differences in the SRDI score were found among cases with the LIV between T12 and L3. However, the SRDI scores of patients with LIV at L4 were significantly higher than those of patients with other LIV levels.

Conclusions: Various degrees of SRD occurred after spinal fusion for AIS. The SRDI was significantly correlated with the HRQOL measurements. The SRDI score was highest in patients with the LIV at L4 when compared to those with other LIV levels. Fusion can be safely extended to L3 without significantly increasing SRD.

Keywords: *Adolescent idiopathic scoliosis, Spinal fusion, Stiffness-related disability, Stiffness-related disability index, Lowest instrumented vertebra*

Adolescent idiopathic scoliosis (AIS) is a 3-dimensional deformity that presents as back deformity, rib or lumbar hump, and/or shoulder asymmetry. The primary goals of surgical correction for AIS are to correct deformities, restore balance, and ultimately enhance the quality of life.[1] A substantial body of literature generally shows favorable outcomes after surgical correction of AIS particularly in terms of the health-related quality of life (HRQOL) improvement.[2-6]

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Extensive spinal fusion, particularly if the lumbar spine is involved, inevitably results in lumbar stiffness, which potentially impairs the activities of daily living. Lumbar stiffness can impose various degrees of stiffness-related disability (SRD) during daily activities, particularly requiring lumbar flexion such as picking up an object off the floor, sitting on the floor, cleaning after defecation, wearing pants, and putting on socks. SRD has been well documented in the field of adult spinal deformity (ASD) surgery, and it has been reported that SRD generally worsens with increasing fusion length.[7-15] Although HRQOL generally improves following surgical treatment in patients with AIS, SRD (one of the negative aspects of AIS surgery) needs to be addressed together when evaluating the clinical outcomes even in pediatric patients. In patients with the lowest instrumented vertebra (LIV) ending at the thoracic spine (e.g., selective thoracic fusion), we can expect no or minimal SRD, even after extensive thoracic fusion. However, if the LIV moves down to the lumbar spine, SRD can negatively affect clinical outcomes and patient satisfaction. To the best of our knowledge, few studies have analyzed SRD following surgical correction in patients with AIS. Therefore, the primary aim of this study was to investigate SRD following surgical treatment in patients with AIS, particularly according to the LIV level. The secondary aim was to determine the clinical impact of SRD by comparing the Stiffness-Related Disability Index (SRDI) with legacy HRQOL scores.

METHODS

This study was approved by the Institutional Review Board at Samsung Medical Center (IRB No. 2021-08-013), and due to the retrospective nature of the study, the requirement for informed consent was waived.

Study Cohort

This is a retrospective longitudinal follow-up study, using a postoperative 2-year dataset from a prospectively collected AIS registry at Samsung Medical Center. Patients who underwent posterior surgical correction for AIS between 2014 and 2021 and were followed up for 2 years were screened. Because this study aimed to assess postoperative SRD mostly related to lumbar stiffness, patients with LIV located in the lumbar spine were included. Patients with the LIV at T12 were also included as the reference group. Patients were excluded if they had non-idiopathic conditions such as syndromic, neuromuscular, congenital, or neurofibromatosis scoliosis; had undergone anterior-only correction; had undergone revision surgery; or had not completed the patient-reported outcome measure at 2 years postoperatively.

The curves to be corrected were determined according to curve types of Lenke classification. The LIV was selected based on the current suggestion considering the level of the stable vertebra and last touching vertebra in standing whole spine radiographs and flexibility in fulcrum bending radiographs. The LIV levels were at or above L4 in all cases; thus, there were no patients whose fusion was stopped at or below L5.

Stiffness-Related Disability Index

In 2011, we developed the SRDI to assess daily functional disabilities following long-segmented fusion (Table 1). The SRDI is similar to Lumbar Stiffness Disability Index as previously proposed by Hart et al.,[9] but in SRDI, floor level activities are considered importantly. The clinical utility of this scoring system to assess SRD in ASD patients has been demonstrated in previous studies.[8,14,15] Although the SRDI was initially developed for adult deformity patients, we thought it could be equally applied to pediatric deformity patients because SRDI questionnaires were not confined to adult daily activities. The SRDI questionnaire comprises 4 distinct categories, each containing 3 questions, making a total of 12 components of the questionnaire as follows: (1) sitting on the floor (with knee extension, cross-legged, and

Table 1. Stiffness-Related Disability Index

Category	Item
Sitting on the floor	1. Knee extension
	2. Cross-legged
	3. Squatting
Sanitation activities	4. Washing face
	5. Washing hair
	6. Cleaning after defecation
Lower body activities	7. Wearing pants
	8. Putting on socks
	9. Cutting toenails
Moving activities	10. Going up and down stairs
	11. Standing from a supine position
	12. Getting in or out of car

0, no impairment; 1, mildly impaired but can do alone; 2, markedly impaired and require minor assistance; 3, cannot do without major assistance. Total sum of Stiffness-Related Disability Index ranges from 0 to 36. Higher scores indicate more severe disability.

squatting); (2) sanitation activity (washing face, washing hair, and cleaning after defecation); (3) lower body activity (wearing pants, putting on socks, and cutting toenails); and (4) moving activity (going up and down stairs, standing from a supine position, and getting in or out of a car). Each of the 12 SRDI items was individually assessed based on severity (no impairment, mildly impaired but can do alone, markedly impaired and require minor assistance, and cannot do without major assistance) and scored from 0 to 3, with a total score ranging from 0 to 36. Patients were routinely asked to fill out the SRDI questionnaire at every visit. For this study, the preoperative and 2-year SRDI scores were used to ensure accurate comparison, as SRD changes over time.[14]

Conventional HRQOL Measurement

Conventional HRQOL measurements were performed using legacy measurement tools, such as the Oswestry Disability Index (ODI), Scoliosis Research Society-22 questionnaire (SRS-22), and 36-Item Short Form Survey (SF-36). ODI was used to evaluate the degree of disability. The mean score (range: 0, normal to 5, impossible) for each of the 10 ODI items was determined separately. An analysis of items related to sexual life was not included in this study. Thus, the total ODI scores ranged from 0 to 45. In this study, the ODI scores were converted to percentages (%) of 45 points. The SRS-22 consists of 5 domains: function/activity, pain, self-perceived image, mental health, and satisfaction with treatment. Each item in the SRS-22 questionnaire was scored on a scale of 1 (worst) to 5 (best), and the total scores for each domain were averaged. The SF-36 is 8-domain measurement tool used to assess general health status. It is usually interpreted in 2 ways: a physical component summary (PCS) and a mental component summary (MCS). The PCS and MCS scores range from 0 to 100, with higher scores indicating better HRQOL. Similar to the SRDI, the preoperative and 2-year scores of conventional HRQOL measurements were used in this study.

Statistical Analysis

Data are presented as frequencies with percentages for categorical variables and as means with standard deviations for continuous variables. Demographic data such as sex and age, and baseline data such as Lenke type, uppermost instrumented vertebra (UIV) levels, and LIV levels are described. Changes in SRDI, ODI, SRS-22, and SF-36 scores pre- and postoperatively were analyzed using a paired *t*-test. Pearson's correlation analysis was used to examine the relationship between the SRDI and legacy HRQOL measurements. An analysis of variance (ANOVA) was performed to determine any significant differences in the SRDI scores according to the different levels of LIV. Lastly, we performed ANOVA test to assess the differences in SRDI scores among patients with LIV at L4 according to their UIV levels. Statistical analyses were performed by professional statisticians using SPSS version 27.0.0 (IBM

Table 2. Demographic and Baseline Data

Variable	Value
Total number of patients	174
Sex (male : female)	47 : 127
Age (yr)	13.8 ± 2.6 (10–18)
Cobb angle (°)	61.5 ± 13.5 (29–121)
Lenke type (type 1 : 2 : 3 : 4 : 5 : 6)	
Total (n = 174)	72 : 36 : 20 : 10 : 19 : 17
LIV at T12 (n = 48)	34 : 12 : 2 : 0 : 0 : 0
LIV at L1 (n = 32)	20 : 7 : 5 : 0 : 0 : 0
LIV at L2 (n = 23)	9 : 7 : 4 : 2 : 1 : 0
LIV at L3 (n = 26)	9 : 8 : 3 : 2 : 4 : 0
LIV at L4 (n = 45)	0 : 2 : 6 : 6 : 14 : 17
UIV at T1 (n = 14)	0 : 13 : 0 : 0 : 0 : 1
UIV at T2 (n = 27)	2 : 20 : 1 : 0 : 0 : 4
UIV at T3 (n = 23)	6 : 2 : 7 : 5 : 1 : 2
UIV at T4 (n = 62)	43 : 0 : 7 : 3 : 2 : 7
UIV at T5 (n = 28)	16 : 1 : 5 : 2 : 1 : 3
UIV at T6 (n = 5)	5 : 0 : 0 : 0 : 0 : 0
UIV at T7 (n = 2)	0 : 0 : 0 : 0 : 2 : 0
UIV at T8 (n = 3)	0 : 0 : 0 : 0 : 3 : 0
UIV at T9 (n = 4)	0 : 0 : 0 : 0 : 4 : 0
UIV at T10 (n = 6)	0 : 0 : 0 : 0 : 6 : 0
Number of fused vertebrae	
LIV at T12	9.4 ± 1.4 (7–12)
LIV at L1	10.4 ± 1.3 (9–13)
LIV at L2	11.6 ± 1.8 (6–14)
LIV at L3	11.9 ± 2.9 (8–15)
LIV at L4	11.9 ± 2.9 (7–16)

Values are presented as mean ± standard deviation (range).
LIV: lowest instrumented vertebra, UIV: uppermost instrumented vertebra.

Corp.). Statistical significance was set at $p < 0.05$.

RESULTS

Revision surgeries were performed in 2 patients due to the distal adding-on phenomenon, in 1 patient for rod fracture, and in 2 patients for proximal junctional kyphosis, all of whom were excluded from our cohort. No cases of pseudoarthrosis requiring revision surgery were observed. This study finally included 174 patients (47 men and 127 women) with a mean age of 13.8 years (Table 2). The mean Cobb angle was 61.5°. There were 72 patients with Lenke type 1, 36 with type 2, 20 with type 3, 10 with type 4, 19 with type 5, and 17 with type 6. The UIV ranged from T1 to T10, and the LIV ranged from T12 to L4. The patients with LIV at T12 had an average of 9.4 fused vertebrae, those with LIV at L1 had an average of 10.4, those with LIV at L2 had an average of 11.6, those with LIV at L3 had an average of 11.9, and those with LIV at L4 had an average of 11.9. HRQOL significantly improved after surgery in terms of all items and the total sum of the SRS-22 and PCS of the SF-36 (Table 3). There were no significant postoperative changes in the ODI and MCS scores of the SF-36.

Table 3. Postoperative Changes in ODI, SRR-22 Score, and SF-36

Variable	Preoperative	Postoperative	*p*-value
ODI (%, max score = 100)	10.5 ± 13.4	9.0 ± 9.7	0.129
SRS-22			
FA (max score = 5)	4.3 ± 0.7	4.5 ± 0.6	0.002*
P (max score = 5)	4.4 ± 0.5	4.6 ± 0.6	0.012*
SA (max score = 5)	3.2 ± 0.8	4.2 ± 0.7	< 0.001*
MH (max score = 5)	4.0 ± 0.8	4.2 ± 0.8	0.004*
S (max score = 5)	3.2 ± 0.9	4.3 ± 0.7	< 0.001*
Total sum (max score = 5)	3.8 ± 0.5	4.4 ± 0.6	< 0.001*
SF-36			
PCS (max score = 100)	81.4 ± 15.3	86.0 ± 11.7	0.005*
MCS (max score = 100)	82.0 ± 13.8	82.7 ± 14.6	0.693

Values are presented as mean ± standard deviation.
ODI: Oswestry disability index, SRS-22: Scoliosis Research Society-22 questionnaire, SF-36: 36-Item Short Form Survey, max: maximum, FA: function/activity, P: pain, SA: self-perceived image, MH: mental health, S: satisfaction with treatment, PCS: physical component summary, MCS: mental component summary.
*Statistical significance.

Postoperative Change of SRDI

Among 12 items of SRDI, the scores of 9 items showed significant increase after surgery: sitting with knee extension (from 0.2 to 1.3), sitting cross-legged (from 0.1 to 0.6), squatting (from 0.1 to 0.8), washing hair (from 0.1 to 0.6), wearing pants (from 0 to 0.1), putting on socks (from 0 to 0.2), cutting toenails (from 0 to 0.6), and standing from supine position (from 0 to 0.1) (Fig. 1). There were no significant differences in terms of cleaning after defecation, going up and down stairs, or getting in and out of car. When these items were grouped by category, there were significant increases in scores regarding sitting on the floor (from 0.4 to 2.7), sanitation activity (from 0.1 to 0.8), and lower body activity (from 0.1 to 1.0) (Fig. 2). The moving activity category scores did not show significant changes. The total sum of the SRDI also significantly increased from 1.0 preoperatively to 4.8 postoperatively.

Correlation between the SRDI Items and Other Legacy HRQOL Measures

Pearson correlation analysis between the SRDI and other HRQOL measures showed that the ODI, nearly all domains, and the total sum of the SRS-22, SF-36 PCS, and SF-36 MCS were significantly correlated with the 4 categories and the total sum of SRDI (Table 4). The correlation coefficients ranged from 0.470 to 0.640 for the ODI and from –0.122 to –0.571 for the SRS-22. Among the SRS-22 subdomains, the function/activity domain showed the strongest correlation with SRDI. The correlation coefficient for the SF-36 ranged from –0.186 to –0.484.

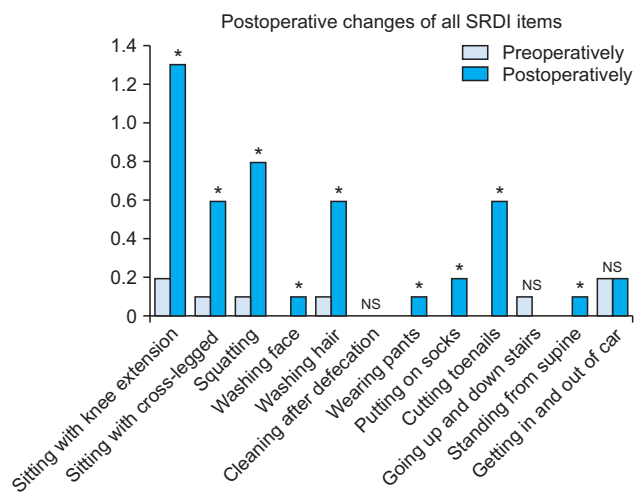

Fig. 1. Postoperative changes of all Stiffness-Related Disability Index (SRDI) items. NS: not significant. *Statistical significance.

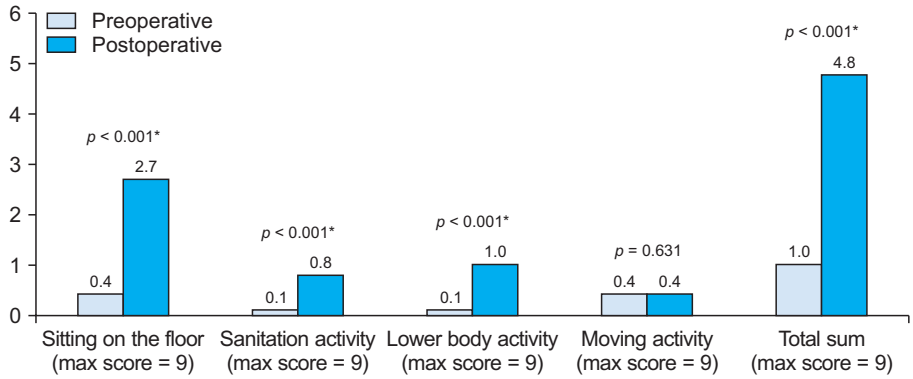

Fig. 2. Categorical changes of Stiffness-Related Disability Index (SRDI) scores. *Statistical significance.

Table 4. Correlation between SRDI Items and Other Legacy HRQOL Measures

Variable	SRDI items	Sitting on the floor	Sanitary activities	Lower body activities	Moving activities	Total sum
ODI	CC	0.519	0.512	0.470	0.506	0.640
	p-value	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*
SRS-22 (FA)	CC	–0.436	–0.500	–0.485	–0.318	–0.571
	p-value	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*
SRS-22 (P)	CC	–0.276	–0.244	–0.254	–0.299	–0.340
	p-value	< 0.001*	0.002*	0.001*	< 0.001*	< 0.001*
SRS-22 (SA)	CC	–0.299	–0.273	–0.185	–0.129	–0.314
	p-value	< 0.001*	< 0.001*	0.019*	0.105	< 0.001*
SRS-22 (MH)	CC	–0.325	–0.312	–0.261	–0.256	–0.381
	p-value	< 0.001*	< 0.001*	0.001*	0.001*	< 0.001*
SRS-22 (S)	CC	–0.202	–0.122	–0.082	–0.084	–0.182
	p-value	<0.010*	< 0.001*	0.302	0.293	0.021*
SRS-22 (total)	CC	–0.282	–0.370	–0.328	–0.292	–0.399
	p-value	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*
SF-36-PCS	CC	–0.484	–0.365	–0.306	–0.186	–0.469
	p-value	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*
SF-36-MCS	CC	–0.366	–0.299	–0.235	–0.250	–0.377
	p-value	< 0.001*	< 0.001*	< 0.001*	< 0.001*	< 0.001*

SRDI: Stiffness-Related Disability Index, HRQOL: health-related quality of life, ODI: Oswestry disability index, CC: correlation coefficient, SRS-22: Scoliosis Research Society-22 questionnaire, FA: function/activity, P: pain, SA: self-perceived image, MH: mental health, S: satisfaction with treatment, SF-36: 36-Item Short Form Survey, PCS: physical component summary, MCS: mental component summary.
*Statistical significance.

Comparison of SRDI According to the LIV Level

There were significant differences in the SRDI scores among the different LIV levels in terms of sitting on the floor, sanitary activity, lower body activity categories, and total sum (Fig. 3). No significant differences were found in moving activity among the LIV levels. These differences in the SRDI among the LIV levels showed similar patterns. No differences were found among the cases with LIV from

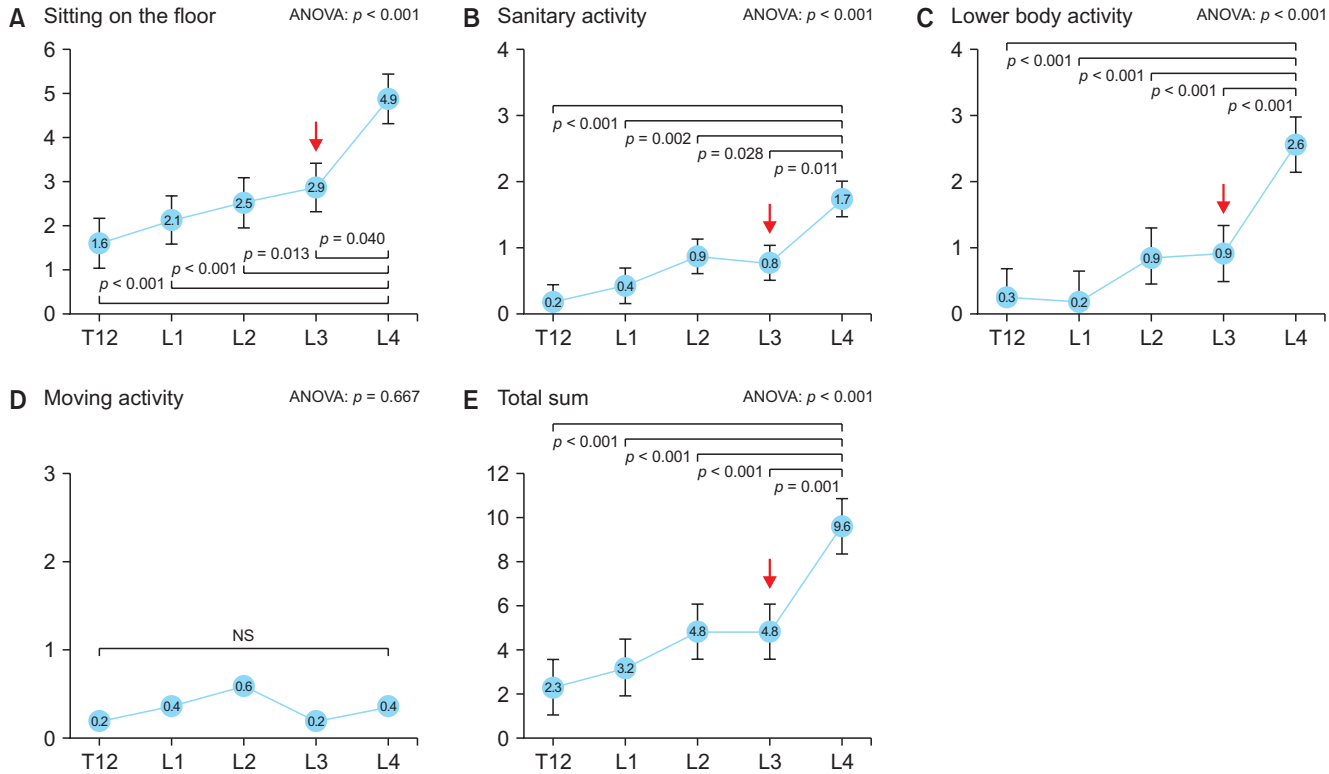

Fig. 3. Comparison of Stiffness-Related Disability Index (SRDI) scores according to the lowest instrumented vertebra (LIV) level. (A) Sitting on the floor. (B) Sanitation activity. (C) Lower body activity. (D) Moving activity. (E) Total sum. There were significant differences in SRDI score among the LIV levels in terms of sitting on the floor, sanitary activity, and lower body activity categories and total sum. Red arrows indicate the point of peak change. ANOVA: analysis of variance, NS: not significant.

Table 5. Subgroup Analysis of SRDI According to UIV Levels in Patients with LIV at L4

Variable	T1–T3 (n = 12)	T4–T7 (n = 17)	T8–T10 (n = 10)	*p*-value (ANOVA)
Sitting on the floor	5.7 ± 3.2	4.7 ± 3.4	4.4 ± 2.6	0.601
Sanitary activities	2.4 ± 2.2	1.7 ± 1.6	1.1 ± 1.9	0.272
Lower body activities	2.8 ± 3.0	2.9 ± 2.9	1.6 ± 2.1	0.447
Moving activities	0.8 ± 1.8	0.3 ± 0.8	0.2 ± 0.6	0.381
Total sum	11.8 ± 7.8	9.5 ± 7.4	7.3 ± 5.9	0.364

Values are presented as mean ± standard deviation.
SRDI: Stiffness-Related Disability Index, UIV: uppermost instrumented vertebra, LIV: lowest instrumented vertebra, ANOVA: analysis of variance.

T12 to L3, although there was a trend of increasing scores from T12 to L3. However, the scores for the LIV with L4 were significantly greater than those for the other LIV levels. Notably, a peak change in the SRDI scores was observed between L3 and L4.

Subgroup Analysis of SRDI According to the UIV Level in Patients with LIV at L4

Subgroup analysis was performed in patients with the LIV at L4 to determine whether the total fusion length affected the degree of SRD (Table 5). In patients with the LIV at L4, 12 patients had UIV at T1-3, 17 at T4-7, and 10 at T8-T10. There were no significant differences in the scores of all categories or in the total sum of the SRDI among the UIV level groups.

DISCUSSION

Spinal fusion surgery with instrumentation has become the definitive treatment for the correction for AIS. Although surgical treatment imposes a physiological and psychologic burden on otherwise healthy adolescents and their families, it can be performed relatively safely, and the postoperative outcomes are generally reported to be favorable. A recent meta-analysis by Aghdasi et al.[16] revealed that surgical correction improved overall HRQOL in patients with AIS during medium- and long-term follow-up. SRS-22 is the most commonly used tool to assess HRQOL in surgically treated patients with AIS. Uehara et al.[4] studied 34 patients who underwent surgical treatment using pedicle screw fixation for Lenke type 1 and 2 AIS. They found that all subscores of SRS-22 were significantly improved compared with those beforehand at ≥ 5-year follow-up. Chau and Hung[17] performed a study to evaluate the HRQOL of AIS patients for up to 30 years postoperatively using SRS-22 questionnaire. They observed that all SRS-22 domain scores except "self-image" domain were relatively stable in the first 10 years until a steady drop starting from the tenth year. Similar to previous reports, we found a significant improvement in HRQOL after surgery in all domains of the SRS-22.

Despite promising results after fusion surgery for AIS, there is always a trade-off between curve correction and loss of mobility. Therefore, we believe that it is necessary to address mobility loss and related functional disabilities together with conventional HQROL evaluation. Helenius et al.[18] studied the spinal mobility and functional outcomes in 78 patients who underwent fusion surgery using Harrington instrumentation. With use of a goniometer, they found decreased lumbar flexion in 18 patients (23%), decreased lumbar extension in 22 patients (28%), and decreased trunk side-bending in 46 patients (59%). However, they concluded that patients could perform, on average, as well as the reference population in non-dynamometric trunk strength tests, including sit-up, arch-up, and squatting. Sanchez et al.[19] performed a similar study on trunk flexibility using a dual digital inclinometer. They divided patients into 3 groups based on the LIV level: group 1 (T12, L1, or L2), group 2 (L3), and group 3 (L4, L5, or S1). They observed that group 3 showed significantly decreased trunk flexibility compared with the other groups. Although 2 previous studies clearly demonstrated that spinal fusion induces flexibility loss to some degree, it is still unclear how this fusion-related stiffness affects daily activities. The 12 items of the SRDI were retrieved through questions about the most uncomfortable daily activities after surgery.[8,14,15] With regard to each item of the SRDI, there was a significant increase in the score in 9 items postoperatively (Fig. 1). Among them, 5 items showed relatively high scores: sitting with knee extension, sitting cross-legged, squatting, washing hair, and cutting toenails. The overall SRD was negligible before surgery with an SRDI total sum of 1.0 out of 36 points (Fig. 2). However, all categories and the total sum showed significant increase in SRDI scores except for the moving activity category. Among the 4 categories, sitting on the floor showed the highest score, indicating that this activity was the most disturbed after surgery. All SRDI categories were closely correlated with other HRQOL measures such as the ODI, SRS-22, and SF-36. That means that SRD can affect postsurgical patient-perceived outcomes, even in pediatric patients with idiopathic scoliosis. SRD seems to be more closely associated with pain or physical function, considering correlation power was relatively high in ODI score, "function/activity" domain of SRS-22, and physical component score of SF-36.

We can hypothesize that the degree of SRD differs according to LIV levels. In the current study, the SRDI scores differed significantly according to the LIV group (smallest in the T12 group and greatest in the L4 group), except for the moving activity category (Fig. 3). Intergroup peak changes in scores were observed between L3 and L4 groups. The total sum of the SRDI was 4.8 points in the L3 group and 9.6 in the L4 group. When the total sum of SRDI is converted to impairment degree, 12 points approximately correspond to "mildly impaired but can do alone." Subanalysis showed that the SRDI score was not significantly different among the UIV level groups in the L4 group (Table 5). Therefore, it can be inferred that once spinal fusion is performed down to L4, the patient would experience mild impairment in daily activities regardless of the UIV level. In contrast, no significant differences in the SRDI scores were observed among the groups with the LIV at or above L3. Even when compared with the T12 group, the SRDI scores of the L1, L2, and L3 groups did not differ significantly from those of the T12 group. This suggests that concerns about postoperative stiffness should not influence decisions to limit correction to higher vertebral levels such as L1 when L3 correction is indicated. This finding is important as it challenges the current practice and provides reassurance that correcting to L3 does not significantly increase SRD. Patients in these groups may not experience substantial SRD, considering that the maximum score of these groups was 4.8 out of a total of 36 points.

Our study has several limitations that should be considered when interpreting the findings. First, the rela-

tively short postoperative follow-up period of 2 years may not be adequate to fully assess long-term functional disability and quality of life outcomes following surgical correction of AIS. Functional disability and quality of life can change over a long period, and the long-term impact of these surgeries could therefore be underestimated or overlooked. Second, the SRDI may not capture the complete range of functional disabilities experienced by patients with AIS. The complexity of real-life activities and individual lifestyle differences can pose challenges in accurately quantifying functional disabilities. Third, the smaller sample sizes for patients with LIV at L3 (n = 26) and at L4 (n = 39), compared to those with LIV at T12 (n = 51), may limit the statistical power of our analysis. Lastly, although we did not include postoperative radiological alignment data, such as lumbar lordosis, facet degeneration, and lateral listhesis, we acknowledge that including these parameters could offer additional insights without altering the study's main conclusions.

In conclusion, various degrees of SRD occurred after spinal fusion in patients with AIS. The SRDI was significantly correlated with HRQOL measures, particularly the pain and function subdomains. The SRDI score was the highest in patients with the LIV at L4 compared to those with other LIV levels. However, there were no significant differences in SRDI scores among patients with other LIV levels at L3 and above. Surgeons can safely extend fusion to L3 without increasing SRD, optimizing deformity correction without compromising outcomes.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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REFERENCES

1. Weinstein SL, Dolan LA, Cheng JC, Danielsson A, Morcuende JA. Adolescent idiopathic scoliosis. Lancet. 2008;371(9623):1527-37.
2. Chau WW, Ng BK, Hung AL. Health-related quality of life (HRQOL) of adolescent idiopathic scoliosis (AIS) patients from surgery to after 30 years using SRS-22 questionnaire. Spine Deform. 2020;8(5):951-6.
3. Akazawa T, Kotani T, Sakuma T, et al. Midlife changes of health-related quality of life in adolescent idiopathic scoliosis patients who underwent spinal fusion during adolescence. Eur J Orthop Surg Traumatol. 2018;28(2):177-81.
4. Uehara M, Takahashi J, Ikegami S, et al. Mid-term results of computer-assisted skip pedicle screw fixation for patients with Lenke type 1 and 2 adolescent idiopathic scoliosis: a minimum five-year follow-up study. J Orthop Sci. 2018;23(2):248-52.
5. Gardner A, Cole A, Harding I. What does the SRS-22 outcome measure tell us about spinal deformity surgery for Adolescent Idiopathic Scoliosis in the UK? Ann R Coll Surg Engl. 2021;103(7):530-5.
6. Weigert KP, Nygaard LM, Christensen FB, Hansen ES, Bunger C. Outcome in adolescent idiopathic scoliosis after brace treatment and surgery assessed by means of the Scoliosis Research Society Instrument 24. Eur Spine J. 2006;15(7):1108-17.
7. Lee CS, Chung SS, Shin SK, Park SJ, Lee HI, Kang KC. Differences in post-operative functional disability and patient satisfaction between patients with long (three levels or more) and short (less than three) lumbar fusions. J Bone Joint Surg Br. 2011;93(10):1400-4.
8. Park JS, Lee CS, Park SJ, Lee KJ, Yum TH. Minimum three-year follow-up of specific functional disabilities after multilevel lumbar fusion: comparison of long-level and short-level fusion. Spine (Phila Pa 1976). 2019;44(20):1418-25.
9. Hart RA, Pro SL, Gundle KR, Marshall LM. Lumbar stiffness as a collateral outcome of spinal arthrodesis: a preliminary clinical study. Spine J. 2013;13(2):150-6.
10. Yoshida G, Boissiere L, Larrieu D, et al. Advantages and disadvantages of adult spinal deformity surgery and its impact on health-related quality of life. Spine (Phila Pa 1976). 2017;42(6):411-9.
11. Bafus T, Shea M, Hart R. Impairment of perineal care functions after long fusions of the lumbar spine. Clin Orthop Relat Res. 2005;(433):111-4.
12. Kimura H, Fujibayashi S, Otsuki B, Takahashi Y, Nakayama T, Matsuda S. Effects of lumbar stiffness after lumbar fusion surgery on activities of daily living. Spine (Phila Pa 1976). 2016;41(8):719-27.
13. Yoshida G, Hasegawa T, Yamato Y, et al. Minimum clinically

important differences in oswestry disability index domains and their impact on adult spinal deformity surgery. Asian Spine J. 2019;13(1):35-44.

14. Park JS, Lee CS, Kang BJ, Raj A, Shin TS, Park SJ. Time-dependent changes in stiffness-related functional disability after long segmental fusion in elderly patients with adult spinal deformity-minimum 2-year follow-up results. Neurosurgery. 2023;93(3):654-61.
15. Park SJ, Lee CS, Kang BJ, Raj A, Shin TS, Park JS. Factors affecting stiffness-related functional disability after long segmental fusion for adult spinal deformity. Neurosurgery. 2022;91(5):756-63.
16. Aghdasi B, Bachmann KR, Clark D, et al. Patient-reported outcomes following surgical intervention for adolescent idiopathic scoliosis: a systematic review and meta-analysis. Clin Spine Surg. 2020;33(1):24-34.
17. Chau WW, Hung AL. Changes in Health-Related Quality of Life (HRQOL) of a specific group of Adolescent Idiopathic Scoliosis (AIS) patients who came across both bracing and surgery. Indian J Orthop. 2021;55(4):925-30.
18. Helenius I, Remes V, Yrjonen T, et al. Comparison of long-term functional and radiologic outcomes after Harrington instrumentation and spondylodesis in adolescent idiopathic scoliosis: a review of 78 patients. Spine (Phila Pa 1976). 2002;27(2):176-80.
19. Sanchez-Raya J, Bago J, Pellise F, Cuxart A, Villanueva C. Does the lower instrumented vertebra have an effect on lumbar mobility, subjective perception of trunk flexibility, and quality of life in patients with idiopathic scoliosis treated by spinal fusion? J Spinal Disord Tech. 2012;25(8):437-42.