Comparison of Structural Disease Burden to Health-related Quality of Life Scores in 264 Adult Spinal Deformity Patients With 2-Year Follow-up

Novel Insights into Drivers of Disability

Joshua Bakhsheshian, MD, Justin K. Scheer, BS,† Jeffrey L. Gum, MD,‡ Lance Horner, BS,§ Richard Hostin, MD,∥ Virginie Lafage, PhD,¶ Shay Bess, MD,# Themistocles S. Protopsaltis, MD,¶ Douglas C. Burton, MD,** Malla Keefe, BS,†† Robert A. Hart, MD,‡‡ Gregory M. Mundis, MD,§§ Christopher I. Shaffrey, MD,∥∥ Frank Schwab, MD,¶ Justin S. Smith, MD, PhD,∥∥ Christopher P. Ames, MD,†† and the International Spine Study Group (ISSG)*

Study Design: This is a review of a prospective multicenter database.

Objective: To investigate the relationship between preoperative disability and sagittal deformity in patients with high Oswestry Disability Index (ODI) and no sagittal malalignment, or low ODI and high sagittal malalignment.

Summary of Background Data: The relationship between ODI and sagittal malalignment varies between each adult spinal deformity (ASD) patient.

Methods: A prospective multicenter database of 365 patients with ASD undergoing surgical reconstruction was analyzed. Inclusion criteria entailed: age 18 years or above and the presence of spinal deformity as defined by a coronal Cobb angle ≥ 20 degrees, sagittal vertical axis (SVA) ≥ 5 cm, pelvic tilt (PT) angle ≥ 25 degrees, or thoracic kyphosis ≥ 60 degrees. Radiographic and health-related quality of life (HRQOL) variables were examined and compared, preoperatively and at 2-year postoperative follow-up. Group 1 (low disability high sagittal—LDHS) consisted of ODI < 40 and SVA ≥ 5 cm or PT ≥ 25 degrees or pelvic incidence-lumbar lordosis ≥ 11 degrees and group 2 (high disability low sagittal—HDLS) consisted of ODI > 40 and SVA < 5 cm and PT < 25 degrees and pelvic incidence-lumbar lordosis < 11 degrees.

Results: Of 264 patients with follow-up, 58 (22.0%) patients were included in LDHS and 30 (11.4%) were included in HDLS. Both groups had similar demographics and preoperative coronal angles. HDLS had worse baseline HRQOL for all measures ($P < 0.05$) except leg and back pain. HDLS had a higher rate of self-reported leg weakness, arthritis, depression and neurological disorder. Both groups had similar 2-year improvements in HRQOL ($P > 0.05$), except only HDLS had a significant Scoliosis Research Society Mental improvement and a significantly higher rate of reaching minimal clinically important differences in Scoliosis Research Society Mental scores ($P < 0.05$).

Conclusions: There is an association of worse baseline HRQOL measures, weakness, arthritis, and mental disease in HDLS. Furthermore, HDLS patients demonstrated similar improvements to LDHS. However, HDLS had greater improvements in the mental domains, perhaps indicating the responsiveness of the mental disability to surgical treatment.

Level of Evidence: Level III.

Key Words: adult spinal deformity, health-related quality of life, HRQOL, sagittal alignment, sagittal vertical axis, mental health

(*Clin Spine Surg* 2017;30:E124–E131)

Received for publication March 1, 2016; accepted October 25, 2016.

From the *Department of Neurological Surgery, Keck School of Medicine, University of Southern California, Los Angeles; †University of California San Diego School of Medicine, La Jolla, CA; ‡Norton Leatherman Spine Center, Louisville, KY; §University of Nevada School of Medicine, Reno, NV; ∥Department of Orthopaedic Surgery, Baylor Scoliosis Center, Plano, TX; ¶Department of Orthopaedic Surgery, NYU Hospital for Joint Diseases, New York, NY; #Rocky Mountain Hospital for Children, Denver, CO; **Department of Orthopaedic Surgery, University of Kansas Medical Center, Kansas City, KS; ††Department of Neurological Surgery, University of California, San Francisco, CA; ‡‡Department of Orthopaedic Surgery, Oregon Health & Science University, Portland, OR; §§Scripps Health, La Jolla, CA; and ∥∥Department of Neurosurgery, University of Virginia Health System, Charlottesville, VA.

Funding for the International Spine Study Group Foundation, through which this study was conducted, is funded through research grants from DePuy Spine and individual donations.

The authors declare no conflict of interest.

Reprints: Joshua Bakhsheshian, MD, Department of Neurological Surgery, Keck School of Medicine, University of Southern California, 1200 North State St. Suite 3300, Los Angeles, CA 90033 (e-mail: joshuabakh@gmail.com).

Over the last decade there has been an increasing interest in the sagittal alignment of patients with adult spinal deformity (ASD). These sagittal alignment measurements include the sagittal vertical axis (SVA), pelvic compensatory parameters (pelvic tilt—PT) and the mismatch between lumbar lordosis and pelvic incidence (PI-LL). Of all the radiographic parameters, including coronal parameters, these sagittal alignment measurements have consistently been shown to have the strongest correlations with health-related quality of life (HRQOL) outcomes in patients with ASD.[1–3] Specifically, SVA has been shown to correlate with Oswestry Disability Index (ODI) and the Physical Component Score (PCS) of Short Form-36 (SF-36). Despite these correlations being the strongest, the relationship can widely vary between individual patients and the correlation is considered only weak to moderate overall ($\rho = 0.29–0.55$).[1]

Given these correlation coefficients, sagittal alignment does not completely account for the disability score of all ASD patients that receive surgical treatment. Furthermore, reaching a minimal clinically important difference (MCID) is not always achieved for ASD patients, as some patients demonstrate no changes in ODI even with large improvements in sagittal malalignment. There are subsets of ASD patients at the extremes of disability and structural deformity that demonstrate unexpected ODI and sagittal alignment relationships. These subsets either have high ODI and no sagittal malalignment, or low ODI and high sagittal malalignment. The drivers of disability in the former patients are less defined, and treating these patients may be more difficult due to potential confounders in their ODI scores. The compression of neural elements causing increased weakness can be a contributing factor to high ODI scores. Other contributing factors may include preoperative coronal alignment of the spine,[4] demographics or other HRQOL measurements and comorbidities.[5]

Understanding other factors that can alter the relationship between sagittal alignment and ODI scores may provide additional criteria to help predict individualized outcomes following the surgical correction of ASD. Thus, we sought to investigate the relationship between preoperative disability and spinal sagittal alignment by examining patient characteristics at the extremes of these values. The hypotheses was that patients with reported HDLS structural deformity have other factors contributing to their disability and have worse 2-year outcomes from spine surgery than those patients with LDHS malalignment.

METHODS

Patient Population

This is a retrospective review of a prospective ASD database from 11 sites across the United States. The database is double-checked by independent reviewers and undergoes periodic quality control checks. Each site enrolled patients into an Institutional Review Board-approved protocol. Inclusion criteria for the database were age 18 years or above and presence of spinal deformity, as defined by the presence of at least one of the following: coronal Cobb angle ≥ 20 degrees, SVA ≥ 5 cm, PT ≥ 25 degrees, and/or thoracic kyphosis (TK) ≥ 60 degrees. Exclusion criteria included spinal deformity of a neuromuscular etiology or presence of active infection or malignancy. Patients that were missing data due to being lost to follow-up were not included.

Two patient groups were identified using the cutoff point of ODI defined as moderate-severely disabled (ODI > 40) and reported thresholds of sagittal spinal malalignment for SVA, PT, and PI-LL.[6] Group 1 (LDHS) was defined as an ODI < 40 and the presence of at least one of the sagittal parameters above the established thresholds (SVA ≥ 5 cm or PT ≥ 25 degrees or PI-LL ≥ 11 degrees), and group 2 (HDLS) was defined as ODI > 40 and no sagittal malalignment (all 3 of the sagittal parameter below the established thresholds: SVA < 5 cm and PT < 25 degrees and PI-LL < 11 degrees).

Demographics and HRQOL Measurements

The demographic data included age, sex, body mass index, Charlson Comorbidity Index,[7] individual comorbidities, and work status. The surgical data included American Society of Anesthesiologists physical status classification, length of hospital stay, operating room time, estimated blood loss, and the number of patients that had at least one direct decompression. Standardized HRQOL measures included the ODI, SF-36, and Scoliosis Research Society-22r (SRS-22r). The SRS-22r provides multiple subdomains (activity, pain, appearance, mental, and satisfaction) and a total score. A numeric rating scale score ranging from 0 (no pain) to 10 (worst pain) was individually collected for back and leg pain. MCID values have previously been established for HRQOL measurements.[8,9] To analyze clinically relevant changes, analysis for differences in the proportions of patients reaching MCID for each HRQOL measure were also analyzed. The MCID values used in the present study included: ODI (−15), PCS (+5.2), back and leg pain numeric rating scale (−2), SRS Activity (+0.375), SRS Pain (+0.587), SRS Image (+0.8), and SRS Mental (+0.42).[8–10]

Radiographic Assessment

All radiographic measures were performed at a central location using standardized techniques.[11] Standing lateral spine radiographs (36" cassette) at baseline and 2-year follow-up were analyzed using validated software (Spineview; ENSAM, Laboratory of Biomechanics, Paris, France).[12,13] Measurements analyzed included: coronal Cobb angles of thoracic and lumbar curves, TK (T2–T12; Cobb angle between superior endplate of T2 and inferior endplate of T12), LL (Cobb angle between superior endplate of L1 and superior endplate of S1), SVA (C7 plumbline relative to S1), PT (angle formed by a line drawn from the midpoint of the sacral endplate to the center of the bicoxofemoral axis and a vertical plumbline extended from the bicoxofemoral axis), PI (angle formed by a line drawn between the center of the femoral head and the sacral endplate and a line drawn perpendicular to the center of the sacral endplate), and PI-LL mismatch (difference between LL and PI).

On the basis of the radiographic parameters, patients were stratified by the SRS-Schwab ASD classification as previously described[14] for the coronal curve locations. The coronal curve type was based on the maximal coronal angle measured according to standard Cobb technique. The 4 types include the following: type T: patients with a thoracic major curve of > 30 degrees (apical level of T9 or higher), type L: patients with a lumbar or thoracolumbar major curve of > 30 degrees (apical level of T10 or lower), type D: patients with a double major curve (1 T and 1 L curves), with each curve > 30 degrees, and type N: patients with no coronal curve > 30 degrees (ie, no major coronal deformity).

Statistical Analyses

Continuous variables were described with the mean and SD. Normality of data were determined using the Shapiro-Wilk test. Comparison of means between the groups initially included an analysis of variance or Kruskal-Wallis test when appropriate, which was followed by pairwise comparisons using the Tukey Honest Significant Difference test to control for type I error or Wilcoxon summed ranked tests where appropriate. Frequency analyses for meeting MCID and for the proportions of comorbidities between the groups were conducted using the Pearson χ^2 analysis. All statistical analyses were conducted using commercially available software (SPSS version 22; IBM, Armonk, NY) and the level of significance was set at $P < 0.05$ for all tests.

Reporting Guidelines

This article adhered to the guideline of STrengthening the Reporting of OBservational studies in Epidemiology (STROBE).[15]

RESULTS

Patient Selection

Of the total 365 patients available, 264 (72.3%) patients were followed for 2 years and 99 (28.6%) were lost to follow-up (Fig. 1). From 264 patients, 88 (33.3%) patients met the inclusion criteria for LDHS (ODI < 40 and SVA ≥ 5 cm or PT ≥ 22 degrees or PI-LL ≥ 11 degrees) or HDLS (ODI > 40 and SVA ≤ 5 cm and PT ≤ 22 degrees and PI-LL ≤ 11 degrees). LDHS consisted of 58 (22.0%) patients and HDLS consisted of 30 (11.4%) patients.

Preoperative Baseline Characteristics

Both groups had similar sex ratio, age, body mass index, Charlson Comorbidity Index, and American Society of Anesthesiologists (Table 1). LDHS had a significantly larger mean value for SVA, PT, PI-LL ($P < 0.01$), and TK ($P < 0.03$). Both groups had similar coronal alignments, when compared by the level of curve apex or by SRS-Schwab coronal curve classification (Tables 1, 2). HDLS had worse baseline HRQOL for all measures ($P < 0.05$) except SRS satisfaction, leg pain and back pain in which the groups were statistically similar

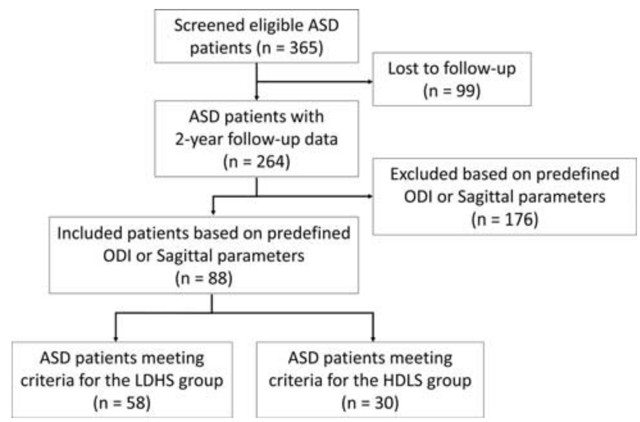

FIGURE 1. Flow diagram of the selected patients for each group. ASD indicates adult spinal deformity; ODI, Oswestry Disability Index, LDHS, low disability high sagittal; HDLS, high disability low sagittal.

(Table 3). HDLS had a significantly higher rate of the following self-reported comorbidities: leg weakness, arthritis, depression, and neurological disorder ($P < 0.05$) (Table 4). Work status was similar between the groups ($P > 0.05$).

Two-Year Postoperative Outcomes

When examining surgical data, both groups had similar length of hospital stay, estimated blood loss, and number of patients undergoing a direct decompression (Table 1), except HDLS had a significantly longer time in the operating room (433 vs. 355 min, $P = 0.01$). At 2 years postoperative, patients in LDHS demonstrated a

TABLE 1. Demographics and SRS-Schwab Classification of the Coronal Curve Deformity at Baseline for all Patients and Each Group

Demographics	LDHS	HDLS	*P*
No.	58	30	—
Age	54.2 ± 15.9	52.7 ± 12.7	0.37
Female:male	48:10	26:4	0.63
BMI	26.4 ± 5.6	25.6 ± 4.3	0.86
CCI	1.1 ± 1.3	1.5 ± 1.6	0.23
ASA	2.1 ± 0.7	2.3 ± 0.6	0.16
LOS	7.3 ± 3.3	7.1 ± 2.3	0.98
OR time	355 ± 132.9	432.9 ± 127.3	**0.01**
EBL	1589.8 ± 1542.2	1460.3 ± 1372.4	0.71
Decompressed (%)	63.8	43.3	0.07
Preoperative SRS-Schwab coronal curve [n (%)]			
Type N	13 (22.4)	5 (16.7)	
Type T	2 (3.4)	2 (6.7)	0.33
Type L	19 (32.8)	15 (50)	
Type D	24 (41.4)	8 (26.7)	

The values in this table show mean ± SD, unless indicated otherwise.
LDHS and HDLS groups were compared; and *P*-values < 0.05 were considered statistically significant.
Please see Figure 1 for description of the 4 coronal curve types.
ASA indicates American Society of Anesthesiologists; BMI, body mass index; CCI, Charlson Comorbidity Index; EBL, estimated blood loss; HDLS, high disability low sagittal; LDHS, low disability high sagittal; LOS, length of hospital stay; OR time, operating room time; SRS, Scoliosis Research Society.

TABLE 2. Radiographic Alignment Measurements for LDHS and HDLS at Baseline and 2-Year Postoperative Follow-up

	Preoperative			2-y Postoperative			2-y Diff (*P*)*	
Radiographic	LDHS	HDLS	*P*	LDHS	HDLS	*P*	LDHS	HDLS
PT	26.8 ± 9.2	15.8 ± 4.9	< 0.01	24.4 ± 10.2	17.4 ± 8.3	< 0.01	0.09	0.46
PI-LL	20.1 ± 16.5	−4.8 ± 10.4	< 0.01	8.8 ± 14.1	−2 ± 14.3	< 0.01	< 0.01	0.44
TK	28.7 ± 19.7	38.7 ± 19.6	0.03	42.1 ± 17.6	48.1 ± 18	0.17	< 0.01	0.02
SVA (mm)	62.4 ± 52.2	−11.1 ± 34.3	< 0.01	36.6 ± 57.6	7.8 ± 42.8	0.04	< 0.01	0.07
UT Cobb	25.8 ± 10.6	25.1 ± 11.1	0.84	20.5 ± 9.8	16.8 ± 7.6	0.31	0.06	0.04
TH Cobb	34.6 ± 12.6	36.5 ± 18.6	0.93	21.2 ± 12.9	14.1 ± 9	0.11	< 0.01	< 0.01
TL Cobb	48 ± 21.7	45.2 ± 23.2	0.52	26.9 ± 18	17.7 ± 19.5	< 0.01	< 0.01	< 0.01
LL Cobb	37.1 ± 19.7	28.5 ± 11.7	0.13	18.8 ± 15.7	10.6 ± 9.8	0.03	< 0.01	< 0.01

The values in this table show mean ± SD, unless indicated otherwise.

*Two-year difference (Diff) values were obtained by comparing improvements between both groups. Cobb angles classified as upper thoracic (UT), thoracic (TH), thoracolumbar (TL), and lower lumbar (LL) based on the curve apex.

HDLS indicates high disability low sagittal; LDHS, low disability high sagittal; PI, pelvic incidence; PT, pelvic tilt; SVA, sagittal vertical axis; TK, thoracic kyphosis.

P-values < 0.05 were considered statistically significant.

significant improvement in PI-LL, SVA, and TK ($P < 0.01$), but not PT ($P = 0.09$). Patients in HDLS demonstrated a significant improvement in TK only ($P = 0.02$). When the groups were compared with each other at 2 years, PT, PI-LL, and SVA remained significantly higher in LDHS (Table 2), and TK was the same between both groups. When comparing 2-year differences in both groups, LDHS demonstrated a more significant improvement in PT, PI-LL, and SVA ($P < 0.01$). Both groups demonstrated similar improvements in coronal Cobb angles ($P < 0.05$ for all).

When assessing reported quality outcomes at 2 years postoperative, LDHS demonstrated significant improvements in all HRQOL measurements except mental component summary score (MCS) and SRS Mental (Table 3). HDLS demonstrated significant improvements in all HRQOL measurements except MCS and leg pain. When the groups were compared with each other at 2 years, HRQOL measurements were worse in HDLS, except SRS appearance, SRS satisfaction, back and leg pain were similar. When compared with each other, both groups had similar 2-year improvements in HRQOL with the exception of HDLS having a significant SRS Mental improvement and a significantly higher rate of reaching SRS Mental MCID (Table 5). HDLS also demonstrated a lower rate of 2-year postoperative improvement in leg pain. Case examples of patients from each group are presented in Figures 2 and 3.

DISCUSSION

The metrics of ODI are generally related to back pain and how it relates to the patient's functional status.[16] Back pain can be due to a large number of etiologies, including alignment issues. The etiology of the pain that drives ODI can also depend on the patient population. Sagittal malalignment has been shown to negatively impact ODI, but the magnitude of impact is not the same for all patients, potentially making some patients more challenging to treat with surgery. To further assess the

TABLE 3. HRQOL Measurements for LDHS and HDLS at Baseline and 2-Year Postoperative Follow-up

	Preoperative			2-y Postoperative			2-y Diff (*P*)*	
HRQOL	LDHS	HDLS	*P*	LDHS	HDLS	*P*	LDHS	HDLS
ODI	26.1 ± 10.9	53.4 ± 10.5	**< 0.01**	16.9 ± 18.3	30.2 ± 20.4	**< 0.01**	**< 0.01**	**< 0.01**
PCS	37.9 ± 10	29.5 ± 5.8	**< 0.01**	45.3 ± 11.1	37.7 ± 11.6	**< 0.01**	**< 0.01**	**< 0.01**
MCS	53.2 ± 10.7	40.1 ± 12.7	**< 0.01**	55.3 ± 9.8	45.9 ± 10.6	**< 0.01**	0.25	0.06
SRS Activity	3.5 ± 0.7	2.5 ± 0.8	**< 0.01**	4 ± 1	3.2 ± 1.1	**< 0.01**	**< 0.01**	**0.03**
SRS Pain	3 ± 0.7	2 ± 0.7	**< 0.01**	3.8 ± 1	3 ± 1.3	**< 0.01**	**< 0.01**	**< 0.01**
SRS Appearance	2.8 ± 0.7	2.3 ± 0.6	**< 0.01**	4 ± 0.8	3.7 ± 1.1	0.18	**< 0.01**	**< 0.01**
SRS Mental	4.1 ± 0.7	3 ± 0.8	**< 0.01**	4.2 ± 0.8	3.6 ± 0.7	**< 0.01**	0.13	**< 0.01**
SRS Satisfaction	2.7 ± 1.2	2.5 ± 0.8	0.48	4.4 ± 1	4 ± 1.2	0.05	**< 0.01**	**< 0.01**
SRS Total	3.3 ± 0.5	2.5 ± 0.6	**< 0.01**	4 ± 0.8	3.4 ± 0.9	**< 0.01**	**< 0.01**	**< 0.01**
Back pain NRS	6.7 ± 2.5	7.5 ± 2.1	0.13	2.5 ± 3	4 ± 3.3	0.07	**< 0.01**	**< 0.01**
Leg pain NRS	3.3 ± 3.2	4.1 ± 3	0.28	2 ± 2.8	3.2 ± 3.2	0.06	**0.03**	0.23

The values in this table show mean ± SD, unless indicated otherwise.

Values in bold are statistically significant.

*Two-year difference (Diff) values were obtained by comparing improvements between both groups.

HDLS indicates high disability low sagittal; HRQOL, health-related quality of life; LDHS, low disability high sagittal; NRS, numeric rating scale; ODI, Oswestry Disability Index; PCS, Physical Component Score; SRS, Scoliosis Research Society.

P-values < 0.05 were considered statistically significant.

TABLE 4. Preoperative Medical and Social Comorbidities for Each Group

	n (%)		
Parameter	**LDHS**	**HDLS**	***P***
≥ 1 comorbidity	34 (58.6)	23 (76.7)	0.09
# comorbidities			
0	24 (41.4)	7 (23.3)	
1	13 (22.4)	7 (23.3)	
2	12 (20.7)	8 (26.7)	
3	6 (10.3)	2 (6.7)	0.20
4	2 (3.4)	3 (10)	
5	0	2 (6.7)	
6–9	1 (1.7)	1 (3.3)	
Types			
Bowel incontinence	2 (3.4)	4 (13.3)	0.11
Numbness or tingling in legs	16 (27.6)	15 (50)	0.07
Leg weakness	17 (29.3)	20 (66.7)	**< 0.01**
Bladder incontinence	5 (8.6)	4 (13.3)	0.59
Anemia	3 (5.2)	4 (13.3)	0.19
Arthritis	14 (24.1)	14 (46.7)	**0.03**
DVT	2 (3.4)	2 (6.7)	0.50
Cancer	3 (5.2)	3 (10)	0.41
Depression	6 (10.3)	10 (33.3)	**0.01**
Diabetes	3 (5.2)	0	0.11
Heart disease	4 (6.9)	0	0.06
Hypertension	16 (27.6)	8 (26.7)	0.93
Kidney disease	1 (1.7)	0	0.36
Liver disease	0	0	NA
Pulmonary disease	1 (1.7)	2 (6.7)	0.24
Neurological disorder	0	2 (6.7)	**0.04**
Osteoporosis	6 (10.3)	4 (13.3)	0.68
Peripheral vascular disease	0	1 (3.3)	0.14
Psychiatric disease	2 (3.4)	2 (6.7)	0.50
Gastric ulcer	8 (13.8)	6 (20)	0.46
Smoker	3 (5.2)	3 (10)	0.45
Work status			
Disabled	2 (3.4)	4 (13.3)	0.12
Employed	33 (56.9)	12 (40)	
Retired	11 (19)	4 (13.3)	
Retired due to back pain	1 (1.7)	2 (6.7)	
Unemployed	5 (8.6)	6 (20)	

The values in this table show mean ± SD, unless indicated otherwise.
Values in bold are statistically significant.
DVT indicates deep venous thrombosis; HDLS, high disability low sagittal; LDHS, low disability high sagittal; NA, not available.
P-values < 0.05 were considered statistically significant.

TABLE 5. The Number of Patients that Reached a Minimal Clinically Important Difference in Each Group at 2-Year Postoperative Follow-up

	n (%)		
MCID	**LDHS**	**HDLS**	***P***
ODI	—	—	—
PCS	28 (59.6)	15 (55.6)	0.74
SRS Activity	33 (57.9)	20 (74.1)	0.15
SRS Pain	37 (64.9)	18 (66.7)	0.87
SRS Appearance	43 (75.4)	21 (77.8)	0.81
SRS Mental	15 (26.3)	14 (51.9)	**0.02**

Minimal clinically important difference for ODI could not be calculated since there were limitations in selecting patients that were eligible for MCID changes in ODI.
Values in bold are statistically significant.
HDLS indicates high disability low sagittal; LDHS, low disability high sagittal; MCID, minimal clinically important difference; ODI, Oswestry Disability Index; PCS, Physical Component Score; SRS, Scoliosis Research Society.
P-values < 0.05 were considered statistically significant.

relationship between reported disability and sagittal malalignment in patients that underwent spine surgery, we evaluated and compared the drivers of disability in patients with high disability scores and low to absent sagittal malalignment (HDLS) and in patients with low disability scores despite high sagittal malalignment (LDHS). We demonstrated that HDLS patients reported worse HRQOL scores than LDHS, including the mental health domains. Patients with lower mental health scores rate their health poorly. These patients have frequent psychological distress and social disability due to emotional difficulties. HDLS patients had mental health scores (MCS = 40.1 ± 12.7, SRS Mental = 3 ± 0.8) that were approximately in the 10th–25th percentile of average age-matched controls,[13,17] suggesting a substantial mental health component.

It is important to consider other comorbidities that can impact HRQOL measures and the emotional well-being of patients. HDLS demonstrated a higher rate of leg weakness, arthritis, depression, and self-reported neurological disorder at baseline, when compared with LDHS. The increased leg weakness may be due to a higher rate of myelopathy or radiculopathy due to compression of neural elements. Although this possibility could not be analyzed further, when the number of patients that underwent at least direct decompression of one level was evaluated, they were similar in both groups. Arthritis may be a predominant contributing factor to increased ODI in the absence of sagittal malalignment. This is not surprising, since the ODI questionnaire collects information on how back or leg pain affects the activities of daily life, and arthritis can directly affect these responses. Slover et al[5] also observed worsening baseline PCS and ODI scores with the addition of each comorbidity, and found a strong association in ODI with osteoarthritis. When ASD patients without comorbidities were compared with matched US population norms, the mental health burden was similar.[18] Therefore, addressing comorbidities in ASD patients may help to improve their overall mental health scores.

Mental health outcomes after surgical treatment can also depend on preoperative baseline disability values. Although LDHS and HDLS demonstrated similar improvements in HRQOL measures postoperatively, only HDLS demonstrated a significant improvement in SRS Mental score that also reached MCID. Neither LDHS nor HDLS demonstrated significant improvements in MCS. LDHS had higher mental health scores, making it more difficult to reach MCID in their mental health score due to a ceiling effect. This may also be the result of MCS being a measure of mental health for the general population, whereas SRS Mental is intended to be specific to patients with spinal deformity. Previous studies have also demonstrated that self-reported disability scores were significantly higher in patients with psychological disturbances.[19–21]

Patients categorized at risk or depressed have an equal opportunity to benefit from reconstructive spine

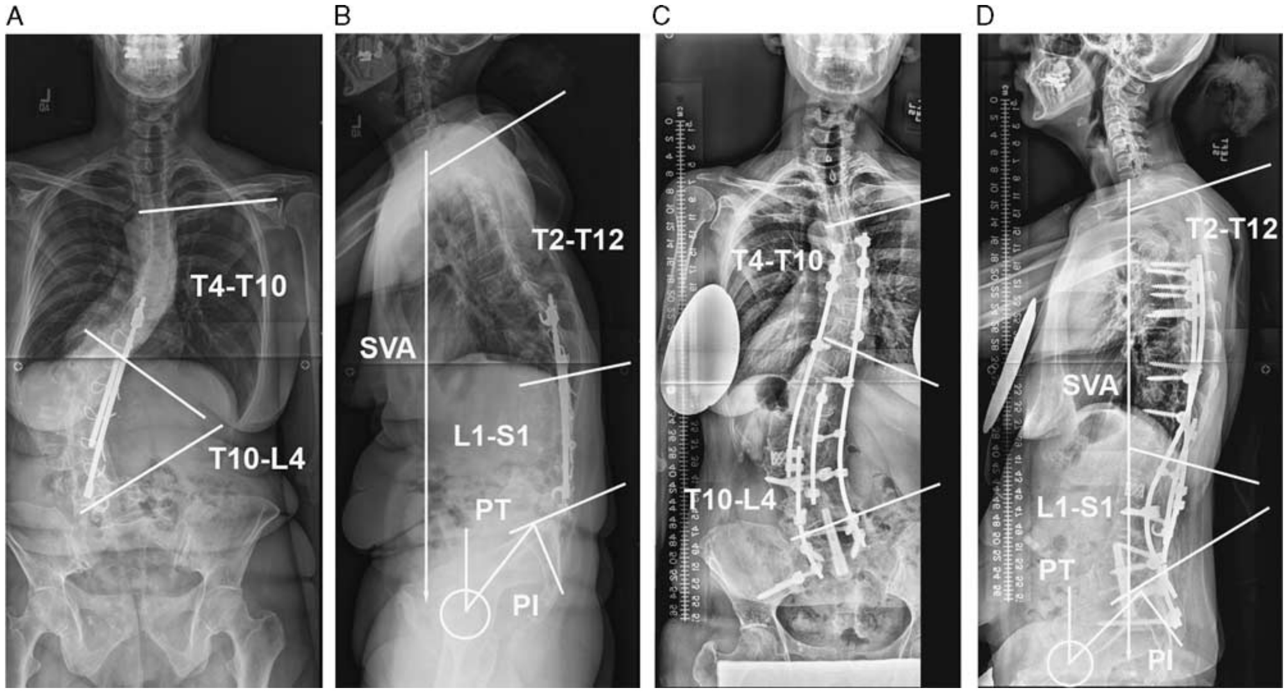

FIGURE 2. A case example of a patient with low disability and high sagittal malalignment from the LDHS group. The patient is a 54-year-old woman with a preoperative ODI of 10 that improved to 9 at 2 years postoperative. There was a history of having a gastric ulcer with no other comorbidities. Preoperative anteroposterior (A) and lateral (B) radiographs with the following measurements: T4–T10 Cobb = 55.3 degrees, T10–L4 Cobb = 76.9 degrees, PT = 42.0 degrees, PI = 61.9 degrees, L1–S1 lumbar lordosis = 14.2 degrees, PI–LL = 47.7 degrees, T2–T12 thoracic kyphosis = 16.0 degrees, C7 SVA = 158.1 mm. Two-year anteroposterior (C) and lateral (D) radiographs with the following values: T4–T10 Cobb = 49.1 degrees, T10–L4 Cobb = 63.2 degrees, PT = 33.0 degrees, PI = 61.8 degrees, L1–S1 lumbar lordosis = 46.5 degrees, PI–LL = 15.3 degrees, T2–T12 thoracic kyphosis = 34.4 degrees, C7 SVA = 14.0 mm. LDHS indicates low disability high sagittal; LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; SVA, sagittal vertical axis.

surgery when compared with patients with higher mental health scores. ASD patients with poor mental and physical health based on MCS and PCS scores have been shown to still demonstrate significant improvements in HRQOL measurements postoperatively.[22] In this report, we also demonstrated that patients with varying self-reported disability and psychological distress significantly improved after spine deformity surgery. Patients with poor preoperative mental health scores can equally benefit from surgery, and may be improved with a more comprehensive treatment approach.

Subjective reporting of pain may display a different relationship in the 2 cohorts investigated in this report. Asher et al[20] previously found that postoperative disability correlated more strongly with pain levels than MCS. Reductions in back pain has also been shown to correlate with improvements in ODI.[23] In the ASD patients included in this study, ODI remained significantly higher in HDLS at 2-years, and a significant difference when comparing preoperative, or postoperative pain levels between LDHS and HDLS between was not observed. Both groups improved in back pain, however only LDHS demonstrated a significantly greater improvement in leg pain when compared with HDLS. This suggests that leg pain may respond differently to surgery in these 2 groups. Further, leg pain can vary in the level of contribution to disability found in these 2 groups.

A major strength of this study is the use of a prospective database with clinical data that was collected through a uniform process from 11 institutions. However, the current study is retrospective and nonrandomized. The findings of this study may be limited to ASD patients with unexpected ODI and sagittal alignment relationships. To limit confounding variables, groups were found to have similar demographics and coronal Cobb values. Self-reported measures may have led to an overestimation of the correlation between mental health parameters and poor physical functioning, and the addition of objective assessments of physical function may reduce this bias. The authors utilized self-reported HRQOL outcomes, namely ODI and SF-36 to assess their relationship. The authors were unable to solely select for patients that were eligible for MCID improvements in ODI in the LDHS group, due to the limited number of patients meeting these criteria. Therefore, analyses for MCID of ODI were not calculated. Furthermore, self-reported assessments of comorbidities, such as neurological disorders, carry inherent limitations due to different individual interpretations.

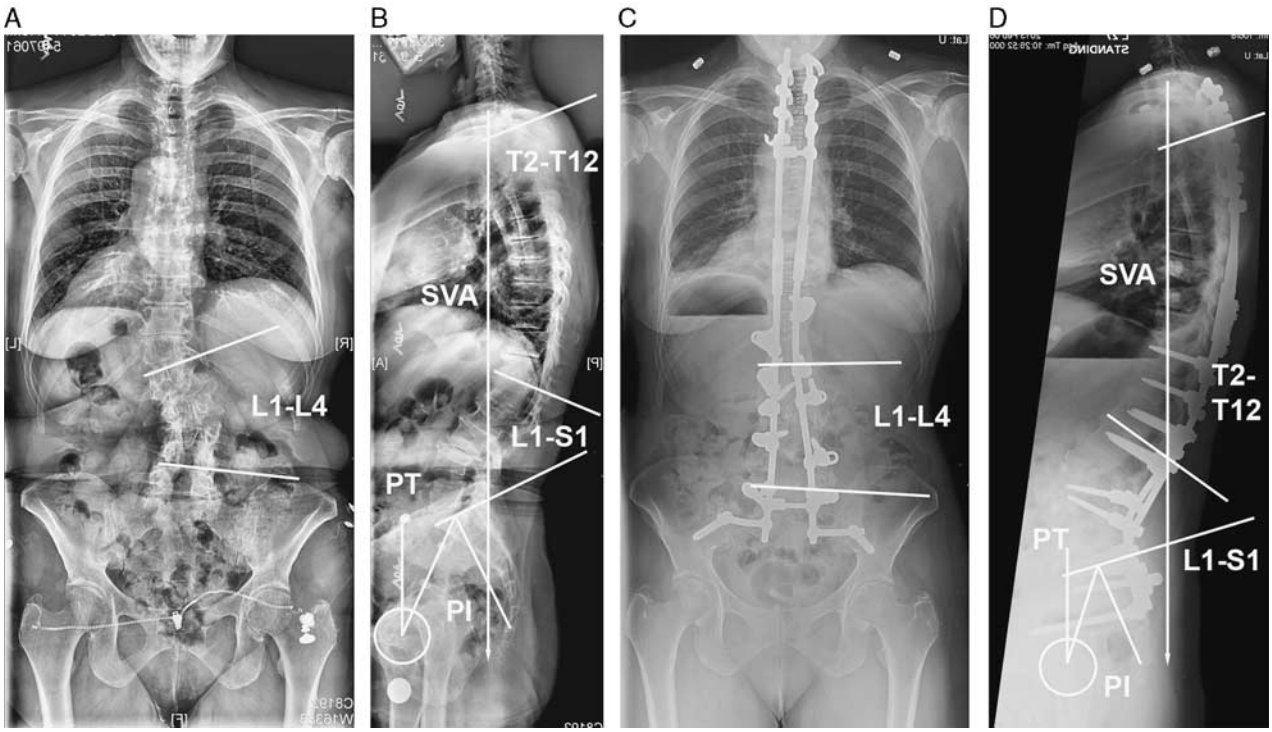

FIGURE 3. A case example of a patient with high disability and no sagittal malalignment from the HDLS group. The patient is a 66-year-old woman with a preoperative ODI of 58 that improved to 36 at 2 years postoperative. The patient's comorbidities included leg weakness, arthritis, and depression. Preoperative anteroposterior (A) and lateral (B) radiographs with the following measurements: L1–L4 Cobb = 22.4 degrees, PT = 16.3 degrees, PI = 42.5 degrees, L1–S1 lumbar lordosis = 50.7 degrees, PI-LL = −8.2 degrees, T2–T12 thoracic kyphosis = 41.6 degrees, C7 SVA = −32.4 mm. Two-year anteroposterior (C) and lateral (D) radiographs with the following values: L1–L4 Cobb = 14.7 degrees, PT = 18.6 degrees, PI = 46.8 degrees, L1–S1 lumbar lordosis = 53.8 degrees, PI-LL = −7.0 degrees, T2–T12 thoracic kyphosis = 43.7, C7 SVA = −71.5 mm. HDLS indicates high disability low sagittal; LL, lumbar lordosis; PI indicates pelvic incidence; PT, pelvic tilt; SVA, sagittal vertical axis.

CONCLUSIONS

There is an association of worse baseline HRQOL measures, weakness, arthritis, and mental disease in patients with high disability and absent sagittal malalignment. These relationships were not due to age or magnitude of coronal deformity because they were similar between both groups. HDLS patients demonstrated similar improvements to those with a low, more proportionate ratio of disability to sagittal malalignment. Furthermore, they had greater improvements in the mental domains, perhaps indicating the responsiveness of the mental disability to surgical treatment.

REFERENCES

1. Glassman SD, Bridwell K, Dimar JR, et al. The impact of positive sagittal balance in adult spinal deformity. *Spine*. 2005;30:2024–2029.
2. 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*. 2009;34:E599–E606.
3. Ames CP, Smith JS, Scheer JK, et al. Impact of spinopelvic alignment on decision making in deformity surgery in adults: a review. *J Neurosurg Spine*. 2012;16:547–564.
4. Glassman SD, Berven S, Bridwell K, et al. Correlation of radiographic parameters and clinical symptoms in adult scoliosis. *Spine*. 2005;30:682–688.
5. Slover J, Abdu WA, Hanscom B, et al. Can condition-specific health surveys be specific to spine disease? An analysis of the effect of comorbidities on baseline condition-specific and general health survey scores. *Spine*. 2006;31:1265–1271.
6. 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*. 2010;35:2224–2231.
7. Charlson M, Szatrowski TP, Peterson J, et al. Validation of a combined comorbidity index. *J Clin Epidemiol*. 1994;47:1245–1251.
8. Blondel B, Schwab F, Ungar B, et al. Impact of magnitude and percentage of global sagittal plane correction on health-related quality of life at 2-years follow-up. *Neurosurgery*. 2012;71:341–348; discussion 8.
9. Copay AG, Glassman SD, Subach BR, et al. Minimum clinically important difference in lumbar spine surgery patients: a choice of methods using the Oswestry Disability Index, Medical Outcomes Study questionnaire Short Form 36, and pain scales. *Spine J*. 2008;8:968–974.
10. Carreon LY, Sanders JO, Diab M, et al. The minimum clinically important difference in Scoliosis Research Society-22 Appearance, Activity, And Pain domains after surgical correction of adolescent idiopathic scoliosis. *Spine*. 2010;35:2079–2083.
11. O'Brien MF, Kuklo TR, Blanke K, et al. Spinal Deformity Study Group. *Radiographic Measurement Manual*. Memphis, TN: Medtronic Sofamor Danek; 2005.
12. Champain S, Benchikh K, Nogier A, et al. Validation of new clinical quantitative analysis software applicable in spine orthopaedic studies. *Eur Spine J*. 2006;15:982–991.

13. Rillardon L, Levassor N, Guigui P, et al. Revue de chirurgie orthopedique et reparatrice de l'appareil moteur [Validation of a tool to measure pelvic and spinal parameters of sagittal balance]. *Rev Chir Orthop Reparatrice Appar Mot*. 2003;89:218–227.
14. Schwab F, Ungar B, Blondel B, et al. Scoliosis Research Society-Schwab adult spinal deformity classification: a validation study. *Spine*. 2012;37:1077–1082.
15. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Epidemiology*. 2007;18:800–804.
16. Fairbank JC, Pynsent PB. The Oswestry Disability Index. *Spine*. 2000;25:2940–2952; discussion 52.
17. Baldus C, Bridwell KH, Harrast J, et al. Age-gender matched comparison of SRS instrument scores between adult deformity and normal adults: are all SRS domains disease specific? *Spine*. 2008;33: 2214–2218.
18. Fu K-MG, Bess RS, Schwab FJ, et al. Health impact comparison of different disease states and population norms to adult spinal deformity (ASD): a call for medical attention. *Spine J*. 2012; 12:S2.
19. Hobby JL, Lutchman LN, Powell JM, et al. The distress and risk assessment method (DRAM). *J Bone Joint Surg Br*. 2001;83:19–21.
20. Asher R, Mason AE, Weiner J, et al. The relationship between preoperative general mental health and postoperative quality of life in minimally invasive lumbar spine surgery. *Neurosurgery*. 2015;76: 672–679.
21. Edwards RR, Klick B, Buenaver L, et al. Symptoms of distress as prospective predictors of pain-related sciatica treatment outcomes. *Pain*. 2007;130:47–55.
22. Bakhsheshian J, Scheer J, Gum J, et al. The impact of low mental health in 264 adult spinal deformity patients with 2-year follow-up. *J Neurosurg Spine*. 2016. [Epub ahead of print].
23. Scheer JK, Smith JS, Clark AJ, et al. Comprehensive study of back and leg pain improvements after adult spinal deformity surgery: analysis of 421 patients with 2-year follow-up and of the impact of the surgery on treatment satisfaction. *J Neurosurg Spine*. 2015; 22:540–553.

