

# Change in Classification Grade by the SRS-Schwab Adult Spinal Deformity Classification Predicts Impact on Health-Related Quality of Life Measures

## *Prospective Analysis of Operative and Nonoperative Treatment*

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**Study Design.** Multicenter, prospective, consecutive series.

**Objective.** To evaluate responsiveness of the Scoliosis Research Society (SRS)-Schwab adult spinal deformity (ASD) classification to changes in health-related quality of life (HRQOL) after treatment for ASD.

**Summary of Background Data.** Ideally, a classification system should describe and be responsive to changes in a disease state. We hypothesized that the SRS-Schwab classification is responsive to changes in HRQOL measures after treatment for ASD.

**Methods.** A multicenter, prospective, consecutive series from the International Spine Study Group. Inclusion criteria: ASD, age more than 18, operative or nonoperative treatment, baseline and 1-year

radiographs, and HRQOL measures (Oswestry Disability Index [ODI], SRS-22, Short Form [SF]-36). The SRS-Schwab classification includes a curve descriptor and 3 sagittal spinopelvic modifiers (sagittal vertical axis [SVA], pelvic tilt, pelvic incidence/lumbar lordosis [PI-LL] mismatch). Changes in modifiers at 1 year were assessed for impact on HRQOL from pretreatment values based on minimal clinically important differences.

**Results.** Three hundred forty-one patients met criteria (mean age = 54; 85% females; 177 operative and 164 nonoperative). Change in pelvic tilt modifier at 1-year follow-up was associated with changes in ODI and SRS-22 (total and appearance scores) ( $P \leq 0.034$ ). Change in SVA modifier at 1 year was associated with changes in ODI, SF-36 physical component score, and SRS-22 (total, activity, and appearance scores) ( $P \leq 0.037$ ). Change in PI-LL modifier at 1 year was associated with changes in SF-36 physical component score and SRS-22 (total, activity, and appearance scores) ( $P \leq 0.03$ ). Patients with improvement of pelvic tilt, SVA, or PI-LL modifiers were significantly more likely to achieve minimal clinically important difference for ODI, SF-36 physical component score (SVA and PI-LL only), SRS activity, and SRS pain (PI-LL only).

**Conclusion.** The SRS-Schwab classification provides a validated system to evaluate ASD, and the classification components correlate with HRQOL measures. This study demonstrates that the classification modifiers are responsive to changes in disease state and reflect significant changes in patient-reported outcomes.

**Key words:** classification, adult spinal deformity, outcomes, pelvis, sagittal alignment, surgery, treatment.

**Level of Evidence:** 3

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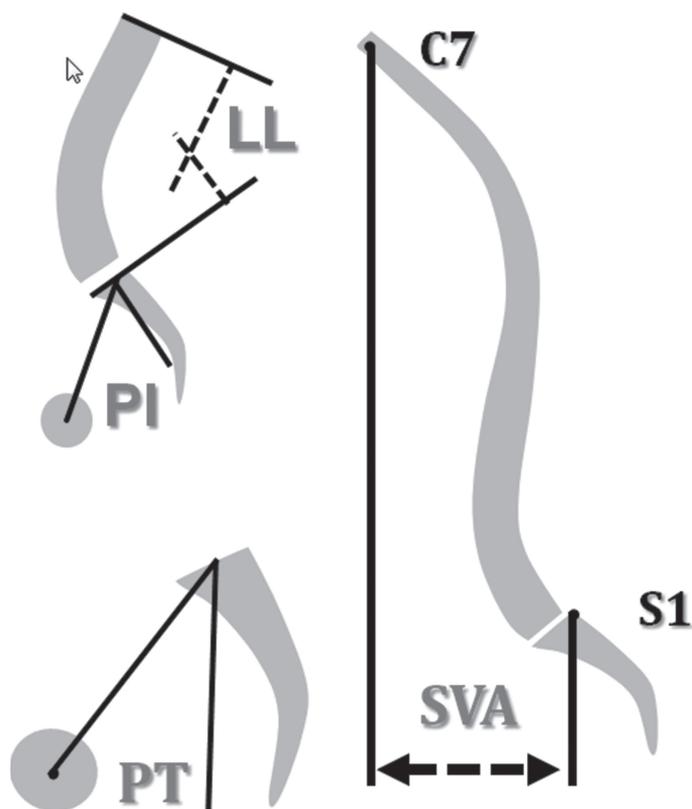
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The term spinal deformity encompasses a remarkably broad range of conditions that can affect individuals across all age groups. Spinal deformity classification systems provide the fundamental nomenclature that enables systematic organization of these disorders. Perhaps more importantly, beyond the simple grouping of various deformity patterns, a



**Figure 1.** Radiographic sagittal modifiers of the SRS-Schwab classification system for adult spinal deformity. SRS indicates Scoliosis Research Society; SVA, sagittal vertical axis; PT, pelvic tilt; PI, pelvic incidence; LL, lumbar lordosis.

classification system should also serve as a guide for patient management and a foundation for evidence-based care.<sup>1</sup>

Historically, the vast majority of spinal deformity studies have focused on adolescents; however, longer life expectancy and advances in surgical techniques, anesthesia care, and spinal instrumentation have created a renewed interest in better understanding, classifying, and treating adult spinal deformity (ASD). Although successful classification systems for adolescent idiopathic scoliosis have been developed and implemented, including the Lenke classification system,<sup>1-3</sup> a widely accepted ASD classification has not been established.<sup>1,4-8</sup> A separate classification system for ASD is warranted by the recognized fundamental differences between adolescent and ASD, including differing clinical presentations, radiographical features, treatment approaches, and prognoses.<sup>4,9-13</sup>

A recent review<sup>1</sup> summarized previously published classification systems for ASD, including the Aebi system, the Scoliosis Research Society (SRS) system,<sup>8</sup> and the Schwab system.<sup>6</sup> However, each of these classification approaches has limitations, and none have been widely adopted. The Aebi system provides a very simple classification based on presumed etiology but provides no substantive detail of the deformity and only allows very broad generalizations regarding treatment approaches.<sup>4</sup> The SRS system includes a rich description of the radiographical features of the deformity, but its clinical relevance and application to patient management are not clear.<sup>8</sup> The Schwab system was developed on the basis

#### 4 Coronal curves type

- T Thoracic only**  
With lumbar curve <30°
- L TL/lumbar only**  
With thoracic curve <30°
- D Double curve**  
With at least one T and one TL/L, both >30°
- N No coronal curve**  
All coronal curves <30°

#### 3 Sagittal modifiers

##### PI minus LL

- 0 : within 10°
- +: moderate 10°-20°
- ++ : marked >20°

##### Global alignment

- 0 : SVA < 4cm
- + : SVA 4 to 9.5cm
- ++ : SVA > 9.5cm

##### Pelvic tilt

- 0 : PT <20°
- + : PT 20°-30°
- ++ : PT >30°

**Figure 2.** The SRS-Schwab Classification includes 4 coronal curves type and 3 sagittal modifiers. PI indicates pelvic incidence; LL, lordosis between L1 and S1; PT, pelvic tilt; SVA, sagittal vertical axis; TL, thoracolumbar.

of studies correlating health-related quality of life (HRQOL) scores and radiographical outcomes, which provides clinical relevance, but it does not include pelvic parameters.<sup>6</sup>

The fundamental role of the pelvis as a link and regulator between the spine and lower limbs has been recently reported by Lafage *et al.*<sup>14,15</sup> Spinopelvic parameters, including the sagittal vertical axis (SVA), pelvic tilt (PT), and the mismatch between the pelvic incidence and the lumbar lordosis (PI-LL) have been shown to be highly correlated with pain and disability and have been used to establish thresholds of correction for realignment procedures.<sup>14,16</sup> Therefore, it has become clear that an effective classification system for ASD must include spinopelvic parameters.

An updated and improved version of the Schwab adult deformity classification, created in conjunction with the SRS, has been recently reported (Figure 1).<sup>7</sup> The parameters for this SRS-Schwab classification were selected on the basis of clinical relevance. This system includes a curve type descriptor and 3 sagittal spinopelvic modifiers (Figures 1, 2). These modifiers are PT, SVA, and PI-LL mismatch. Excellent inter- and intra-rater reliability and inter-rater agreement have been reported for this classification system, demonstrating that its application is easy and consistent.<sup>7</sup> However, the system has not yet been clinically validated, specifically its ability to respond to changes in disease state and whether it reflects significant changes in patient-reported outcomes. This study aims to provide this clinical validation using a large prospective multicenter cohort of patients with ASD. Our working hypothesis was that the SRS-Schwab classification will be responsive to and can predict changes in HRQOL measures from baseline values to 1-year follow-up for patients with ASD treated operatively and nonoperatively.

## MATERIALS AND METHODS

### Patient Population

This is a multicenter prospective study of patients (>18 yr) with ASD. Patients were drawn from the International Spine

**TABLE 1. Minimum Clinical Important Difference Values Used in This Study<sup>19</sup>**

PCS	ODI	SRS Pain	SRS Appearance	SRS Activity	SRS Mental
+5.2 points	-15 points	+0.587 points	+0.8 points	+0.375 points	+0.42 points

PCS indicates Physical Component Score; ODI, Oswestry Disability Index; SRS, Scoliosis Research Society.

Study Group, which is composed of 10 sites across the United States. Patients were enrolled into an institutional review board–approved protocol by each site. Inclusion criteria for the International Spine Study Group database are: scoliosis Cobb angle 20° or more, SVA 5 cm or more, PT 25° or more, and/or thoracic kyphosis 60° or more. In addition to database inclusion criteria, patients were included in this study only if they had complete SRS-Schwab classification parameters as well as completed Oswestry Disability Index (ODI), and SRS-22, and Short Form (SF)-36 questionnaires at baseline and 1 year after treatment.

At the time of entry into the database, patients were classified into either operative or nonoperative treatment groups, based on the initial management approach. The decision of

whether to pursue operative or nonoperative treatment is complex and is ultimately based on patient input and physician counseling.

### Data Collection and Classification

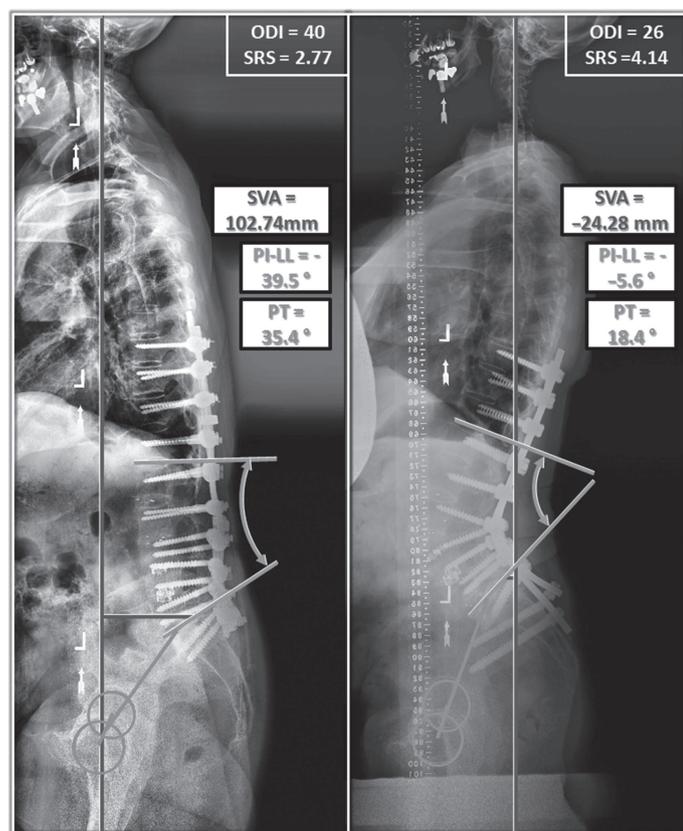
Data collection at baseline and 1 year after treatment (either operative or nonoperative) consisted of standardized HRQOL questionnaires, as well as clinical, demographic, and radiographical information. Full-length free-standing anteroposterior and lateral spine radiographs (36-inch cassette) at baseline and 1-year follow-up were analyzed using validated software<sup>17,18</sup> (Spineview, Surgiview, Paris). All radiographical measures were performed at a single center (NYU Hospital for Joint Diseases) and included: thoracic and thoracolumbar coronal Cobb angles, SVA, PT, and PI-LL mismatch (Figure 2).

At baseline, radiographical parameters were measured to identify the type of curve and the 3 sagittal modifiers of the SRS-Schwab classification of ASD.<sup>7</sup> Sagittal modifiers were also categorized according to the SRS-Schwab classification at 1 year after treatment. HRQOL scores were analyzed at baseline and 1-year follow-up to identify if patients reached thresholds of improvements based on the minimal clinically important difference (MCID, Table 1) after treatment.<sup>19</sup>

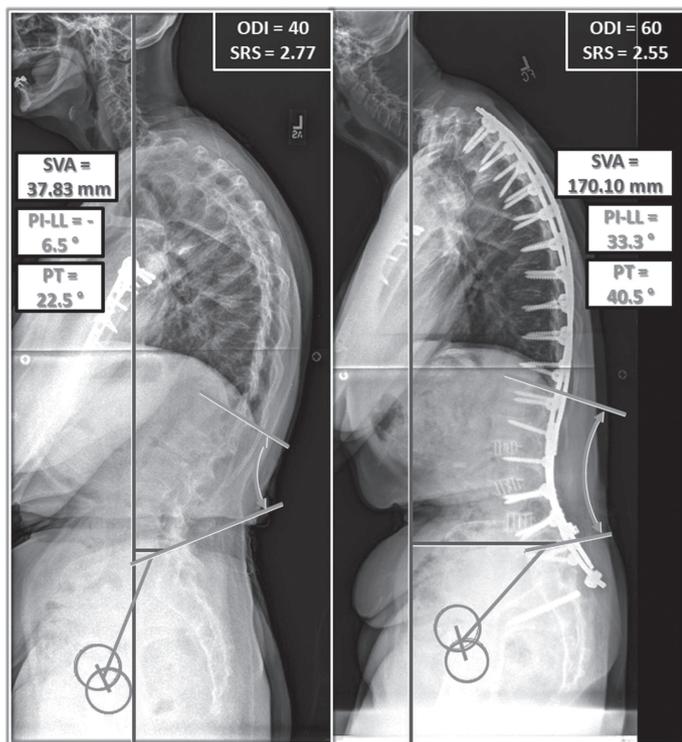
Determination of the cutoff values for the SRS-Schwab classification was performed previously in the setting of a multicenter prospective analysis of 592 adults with spinal deformity. The analysis of the correlation between radiographical (both antero-posterior and lateral) parameters and HRQOL revealed that the 3 parameters that were the most highly correlated with HRQOL were PI-LL, PT, and SVA. On the basis of these findings, a regression analysis between each of these 3 parameters and ODI was used to identify the radiographical threshold corresponding to an ODI 40 or more (PT > 22°, SVA > 47 mm, and PI-LL > 11°).<sup>16</sup>

### Statistical Analysis

Mean and standard deviation were used to describe continuous variables, and frequency analyses were used for categorical variables. Change between baseline and outcomes at 1 year were evaluated using a paired *t* test analysis, and group comparison was carried out using an unpaired *t* test analysis. For each of the SRS-Schwab classification sagittal modifiers, the change in grade was stratified to define 3 exclusive groups: no change in grade between baseline and 1-year follow-up, deterioration by 1 or 2 grades, and improvement by 1 or 2 grades. For each modifier, a comparison between patients who sustained an improvement and those who sustained



**Figure 3.** Example of relationship between change in SRS-Schwab classification modifiers and change in HRQOL. This patient sustained an improvement in modifier grades (PI-LL: ++ to 0; SVA: ++ to 0; PT: ++ to 0), as well as improvement in HRQOL ( $\Delta$  ODI = -20;  $\Delta$  SRS = +1.37). HRQOL indicates health-related quality of life; SVA, sagittal vertical axis; PT, pelvic tilt; PI, pelvic incidence; LL, lumbar lordosis; ODI, Oswestry Disability Index.



**Figure 4.** Example of relationship between change in SRS-Schwab classification modifiers and change in HRQOL. This patient sustained a deterioration in modifier grades (PI-LL: 0 to ++; SVA: 0 to ++; PT: + to ++), as well as deterioration in HRQOL ( $\Delta$  ODI = +20;  $\Delta$  SRS = -1.22). HRQOL indicates health-related quality of life; SVA, sagittal vertical axis; PT, pelvic tilt; PI, pelvic incidence; LL, lumbar lordosis; ODI, Oswestry Disability Index.

deterioration was carried out using an independent *t* test or a  $\chi^2$  analysis. Thresholds for improvement and deterioration in HRQOL values were based on previously reported measures of MCID (Table 1).<sup>19</sup> Patients who did not reach MCID threshold for improvement or deterioration were classified as unchanged. The significance level was set at 0.05.

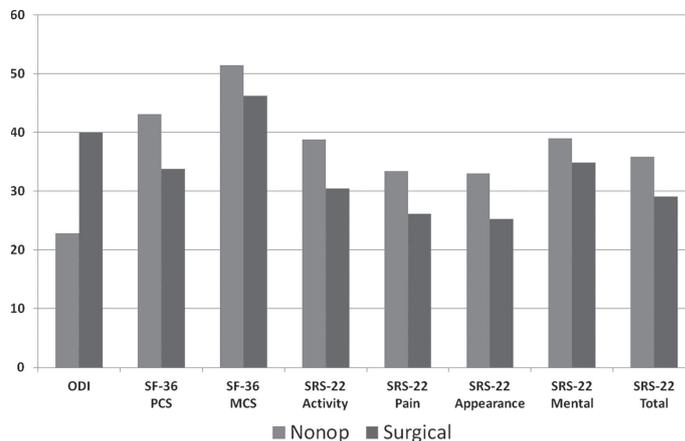
**RESULTS**

**Baseline Analysis**

This study included 341 patients, including 290 females and 51 males, with an average age of 54.4 years ( $\pm$  15.2 yr). In

Parameter	Surgical	Nonoperative	P
N	177	164	NA
Age	55.7 $\pm$ 14.8	52.9 $\pm$ 15.5	0.089
Female sex	83.9%	86%	0.650
BMI	26.5 $\pm$ 5.1	25.0 $\pm$ 5.2	0.01
Prior surgery	36.9%	15.2%	<0.001

*BMI indicates body mass index.*



**Figure 5.** Comparison of baseline HRQOL scores for nonoperative and surgical patients. Note that SRS scores have been multiplied by 10. For each outcomes measure, the difference between nonoperative and surgical patients was statistically significant (unpaired *t* test; *P* < 0.001). HRQOL indicates health-related quality of life; ODI, Oswestry Disability Index; SF, short-form; PCS, physical component score; MCS, Mental Component Score; SRS, Scoliosis Research Society; Nonop, nonoperative.

the nonoperative group, there were 164 patients (141 females and 23 males), with an average age of 52.9 years ( $\pm$  15.5 yr). In the operative group, there were 177 patients (149 females and 28 males), with an average age of 55.7 years ( $\pm$  14.8 yr). Example cases are high lighted in Figures 3 and 4.

Baseline demographic data for operative and nonoperative patients are summarized in Table 2. Operative patients had a significantly higher proportion with a history of prior surgery (36.9%) than nonoperative patients (15.2%; *P* < 0.001). The operative patients also had a higher average body mass index (26.5) than the nonoperative patients (25.0; *P* = 0.01). All other demographic variables, including age and sex distribution, were not significantly different between the 2 groups (*P* > 0.05).

Modifier	Grade	Surgical, %	Nonoperative, %	P
PT	0	40.1	53.7	0.015
	+	37.3	33.5	
	++	22.6	12.8	
SVA	0	51.1	72.8	<0.001
	+	24.4	20.3	
	++	24.4	7.0	
PI-LL	0	52.5	63.4	0.012
	+	18.1	20.7	
	++	29.4	15.9	

*SRS indicates Scoliosis Research Society; SVA, sagittal vertical axis; PT, pelvic tilt; PI-LL, pelvic incidence/lumbar lordosis.*

**TABLE 4. Comparison of HRQOL Between Baseline and 1 Year for Surgical and Nonoperative Patients**

	Surgical			Nonoperative		
	Baseline Mean $\pm$ SD	1 yr Mean $\pm$ SD	<i>t</i> Test <i>P</i>	Baseline Mean $\pm$ SD	1 yr Mean $\pm$ SD	<i>t</i> Test <i>P</i>
ODI score	39.8 $\pm$ 19.2	25.0 $\pm$ 19.0	<0.001	22.9 $\pm$ 16.2	22.2 $\pm$ 16.2	0.37
SF-36 PCS	34.1 $\pm$ 10.3	41.9 $\pm$ 10.7	<0.001	43.2 $\pm$ 10.7	42.7 $\pm$ 10.4	0.323
SF-36 MCS	45.7 $\pm$ 13.8	50.7 $\pm$ 12.7	<0.001	51.6 $\pm$ 10.5	53.1 $\pm$ 9.9	0.023
SRS-22 activity	3.0 $\pm$ 0.9	3.6 $\pm$ 0.9	<0.001	3.9 $\pm$ 0.8	3.9 $\pm$ 0.8	0.771
SRS-22 pain	2.6 $\pm$ 0.9	3.5 $\pm$ 1.0	<0.001	3.3 $\pm$ 1.0	3.5 $\pm$ 0.9	0.003
SRS-22 appearance	2.5 $\pm$ 0.8	3.8 $\pm$ 0.9	<0.001	3.3 $\pm$ 0.7	3.4 $\pm$ 0.7	0.285
SRS-22 mental	3.5 $\pm$ 1.0	3.9 $\pm$ 0.9	<0.001	3.9 $\pm$ 0.8	3.9 $\pm$ 0.8	0.314
SRS-22 total score	2.9 $\pm$ 0.7	3.7 $\pm$ 0.8	<0.001	3.6 $\pm$ 0.6	3.7 $\pm$ 0.6	0.024

*SRS indicates Scoliosis Research Society; ODI, Oswestry Disability Index; SF, Short-Form; SD, standard deviation; PCS, physical component score; MCS, mental component score; HRQOL, health-related quality of life.*

Operative patients had greater baseline disability and poorer HRQOL on all standardized measures assessed, including ODI, SF-36 physical component score (PCS), SF-36 mental component score, SRS-22 total score, and all SRS-22 subscores (Figure 5;  $P < 0.001$ ). Compared with nonoperative patients, operative patients had greater baseline sagittal malalignment (SVA of 51 mm *vs.* 19 mm,  $P < 0.001$ ), greater pelvic retroversion (PT of 22° *vs.* 19°,  $P = 0.014$ ), and greater PI-LL mismatch (12° *vs.* 5°,  $P < 0.001$ ). Operative and nonoperative patient groups did not have significant differences in terms of maximal Cobb angle (48° *vs.* 45°, respectively;  $P > 0.05$ ).

Baseline grades for each of the SRS-Schwab sagittal modifiers (SVA, PT, and PI-LL mismatch) were determined for each of the operative and nonoperative patients (Table 3). Surgical patients had a greater percentage of patients with a PI-LL modifier grade of ++ (29.4% *vs.* 15.9%), an SVA modifier grade of ++ (24.4% *vs.* 7%), and a PT graded as ++ (22.6% *vs.* 12.8%), suggesting a more severely deformed surgical group with recruitment of compensatory pelvic retroversion than the nonoperatively treated patients (Table 3).

### Change Between Baseline and 1 Year

Comparison of HRQOL scores at baseline and 1 year after treatment revealed that, for the operatively treated patient group, there were significant improvements in all of the HRQOL scores and domains (Table 4). In contrast, the patient group treated with nonoperative care demonstrated only modest improvements in SF-36 mental component score, and SRS total score, and pain subscore (Table 4). The improvement in SRS-22 pain subscore for nonoperative patients did not reach MCID; defined MCID values for SF-36 mental component score and SRS-22 total score have not been reported.

The percentage of patients reaching MCID threshold for improvement for each of the standardized measures of HRQOL was calculated (Table 5). For each of the outcomes measures, operatively treated patients were significantly more likely to reach MCID threshold for improvement, compared with the nonoperatively treated patients ( $P < 0.001$ ; Table 5).

Patients treated operatively demonstrated significant radiographical improvement in SVA, PT, and PI-LL mismatch from baseline to 1-year follow-up (Table 6). In contrast, none of the SRS-Schwab sagittal modifiers (SVA, PT, PI-LL mismatch)

**TABLE 5. Percentage of Patients Reaching MCID Thresholds for Improvement at 1 Year After Treatment**

	ODI	SF-36 PCS	SRS-22 Activity	SRS-22 Pain	SRS-22 Appearance	SRS-22 Mental
All (%)	29.6	36.2	40.8	45.2	44.6	29.9
Nonoperative (%)	4.9	16.9	18.9	22.6	13.4	17.7
Surgical (%)	53.6	55.9	61.0	66.1	73.4	41.2

*ODI indicates Oswestry Disability Index; SF, Short-Form; PCS, physical component score; SRS, Scoliosis Research Society.*

**TABLE 6. Comparison of Radiographical Parameters Between Baseline and 1 Year for Surgical and Nonoperative Patients**

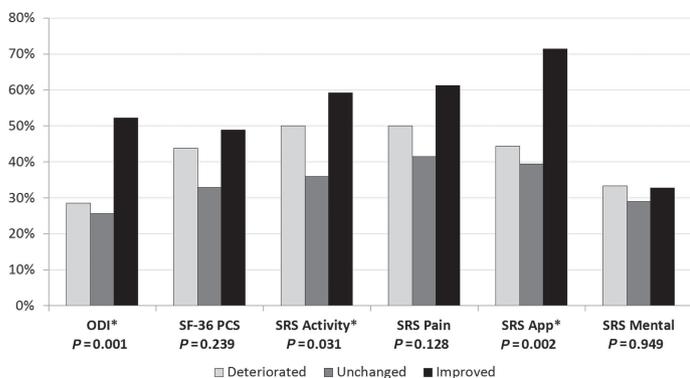
	Surgical			Nonoperative		
	Baseline Mean ± SD	1 yr Mean ± SD	t Test P	Baseline Mean ± SD	1 yr Mean ± SD	t Test P
SVA (mm)	50.7 ± 73.7	18.2 ± 55.9	<0.001	18.5 ± 49.9	22.8 ± 53.4	0.042
PT (°)	22.2 ± 11.1	20.2 ± 10.4	0.001	19.4 ± 9.6	19.5 ± 9.4	0.770
PI-LL	11.9 ± 20.7	1.6 ± 14.2	<0.001	4.8 ± 16.6	5.3 ± 16.8	0.251

*SD indicates standard deviation; SVA, sagittal vertical axis; PT, pelvic tilt; PI, pelvic incidence; LL, lumbar lordosis.*

**TABLE 7. For Each Sagittal Modifier Independently, Comparison of Change in HRQOL Between Patients Who Sustained a Modifier Improvement Versus Those Who Sustained Deterioration**

Modifier	Score	Modifier Deterioration		Modifier Improvement		t Test P
		Mean	SD	Mean	SD	
PT	Δ ODI	-5.55	14.95	-12.60	18.34	0.034
	Δ SF-36 PCS	3.61	10.02	6.63	11.60	Ns
	Δ SF-36 MCS	3.43	12.60	4.32	11.10	Ns
	Δ SRS activity	0.31	0.70	0.50	0.74	Ns
	Δ SRS pain	0.61	0.87	0.86	0.84	Ns
	Δ SRS appearance	0.63	0.92	1.28	1.09	0.002
	Δ SRS mental	0.27	0.65	0.30	0.76	Ns
	Δ SRS total	0.48	0.62	0.79	0.66	0.017
SVA	Δ ODI	-6.52	16.14	-12.88	16.15	0.031
	Δ SF-36 PCS	1.34	9.89	7.20	10.93	0.008
	Δ SF-36 MCS	4.59	10.78	4.24	12.04	Ns
	Δ SRS activity	0.23	0.69	0.52	0.81	0.037
	Δ SRS pain	0.58	0.91	0.84	0.82	Ns
	Δ SRS appearance	0.26	0.88	1.23	1.04	<0.001
	Δ SRS mental	0.29	0.84	0.33	0.82	Ns
	Δ SRS total	0.34	0.69	0.80	0.70	0.001
PI-LL	Δ ODI	-7.99	16.43	-12.67	15.05	Ns
	Δ SF-36 PCS	1.76	9.40	7.12	11.41	0.024
	Δ SF-36 MCS	2.70	11.12	4.44	13.42	Ns
	Δ SRS activity	0.21	0.80	0.53	0.70	0.030
	Δ SRS pain	0.68	0.89	0.86	0.86	Ns
	Δ SRS appearance	0.51	0.94	1.26	1.05	0.001
	Δ SRS mental	0.25	0.67	0.46	0.85	Ns
	Δ SRS total	0.44	0.67	0.83	0.66	0.006

*SD indicates standard deviation; SVA, sagittal vertical axis; PT, pelvic tilt; PI, pelvic incidence; LL, lumbar lordosis; ODI, Oswestry Disability Index; SF, Short-Form; SRS, Scoliosis Research Society; PCS, physical component score; MCS, mental component score; Ns, non significant; HRQOL, health-related quality of life.*

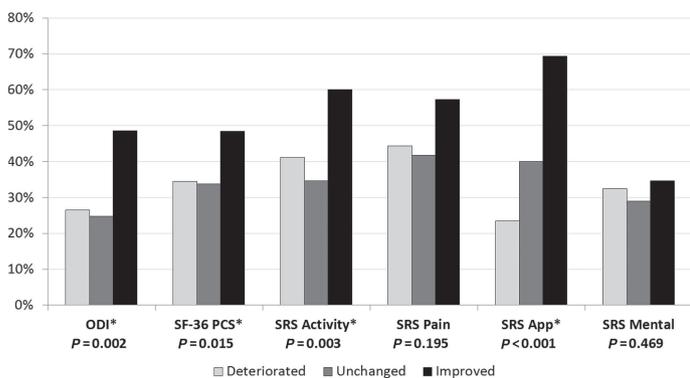


**Figure 6.** Comparison of the percentage of patients reaching MCID for each outcome measure assessed, stratified on the basis of pelvic tilt modifier grade at 1-year follow-up compared with baseline (deteriorated, unchanged, or improved). An asterisk indicates *P* values that reached statistical significance. ODI indicates Oswestry Disability Index; SF, short-form; SRS, Scoliosis Research Society; MCID, minimal clinically important difference; App, appearance.

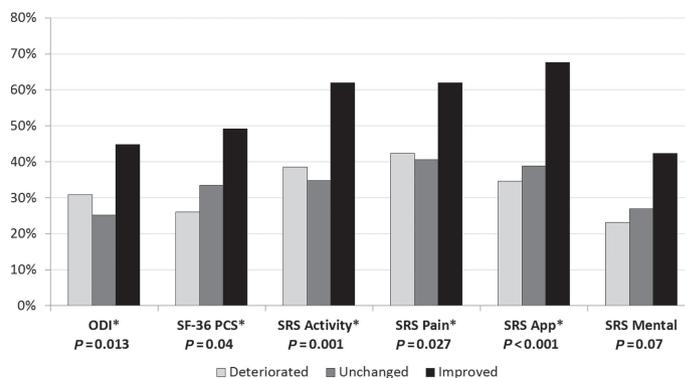
improved significantly in the nonoperative treatment group (Table 6). Nonoperative patients demonstrated a modest but significant deterioration in SVA at 1-year follow-up compared with baseline.

For the combined operative and nonoperative treatment groups, analysis of the SRS-Schwab classification modifiers at 1 year revealed that 34.6% and 15.8% of the patients were classified as + or ++ for the PT modifier, 20.6% and 8.8% were classified as + and ++ for the SVA modifiers, and 16.1% and 14.7% were classified as + and ++ for the PI-LL modifier, respectively. Comparison of modifier classification grades between baseline and 1 year demonstrated that the grades were as follows:

- Unchanged at 1 year for 75.1% (PT), 67.4% (SVA), and 71.6% (PI-LL) of the patients.
- Improved by 1 or 2 grades at 1 year for 14.4% (PT), 22.5% (SVA), and 20.8% (PI-LL) of the patients.



**Figure 7.** Comparison of the percentage of patients reaching MCID for each outcome measure assessed, stratified on the basis of SVA modifier grade at 1-year follow-up compared with baseline (deteriorated, unchanged, or improved). An asterisk indicates *P* values that reached statistical significance. ODI indicates Oswestry Disability Index; SF, short-form; SRS, Scoliosis Research Society; MCID, minimal clinically important difference; App, appearance.



**Figure 8.** Comparison of the percentage of patients reaching MCID for each outcome measure assessed, stratified on the basis of PI-LL mismatch modifier grade at 1-year follow-up compared with baseline (deteriorated, unchanged, or improved). An asterisk indicates *P* values that reached statistical significance. ODI indicates Oswestry Disability Index; SF, short-form; SRS, Scoliosis Research Society; MCID, minimal clinically important difference; PI-LL, pelvic incidence-lumbar lordosis; App, appearance.

- Deteriorated by 1 or 2 grades at 1 year for 10.6% (PT), 10.2% (SVA), and 7.6% (PI-LL) of the patients.

Change in PT modifier (improvement *vs.* deterioration) at 1-year follow-up was associated with corresponding changes in ODI and SRS-22 total and appearance scores ( $P \leq 0.034$ ; Table 7). Change in SVA modifier (improvement *vs.* deterioration) at 1 year was associated with corresponding changes in ODI, SF-36 PCS, and SRS-22 total and activity and appearance subscores ( $P \leq 0.037$ ). Change in PI-LL modifier (improvement *vs.* deterioration) at 1 year was associated with corresponding changes in SF-36 PCS and SRS-22 total and activity and appearance subscores ( $P \leq 0.03$ ).

Patients with improvement of PT modifier grade were significantly more likely to achieve MCID threshold for improvement in ODI, SRS activity, and SRS appearance scores compared with patients who remained unchanged or deteriorated (Figure 6). Patients with improvement of SVA modifier grade were significantly more likely to achieve MCID threshold for improvement in ODI, SF-36 PCS, SRS activity, and SRS appearance scores compared with patients who remained unchanged or deteriorated (Figure 7). Patients with improvement of PI-LL mismatch modifier grade were significantly more likely to achieve MCID threshold for improvement in ODI, SF-36 PCS, SRS activity, SRS pain, and SRS appearance scores compared with patients who remained unchanged or deteriorated (Figure 8).

## DISCUSSION

A remarkable shift in population demographics is underway in many developed countries, with the proportion of elderly expanding to unprecedented levels. For example, the United States Census Bureau estimates that between the years 2000 and 2030, the number of individuals in the United States, at least 65 years of age is expected to double to more than 70 million.<sup>20</sup> As these shifts occur, the medical and surgical

conditions that afflict the elderly will become increasingly prevalent, and the need to better appreciate and effectively manage these conditions will become critical.

Although the precise prevalence of ASD is difficult to define, the prevalence among the elderly has been suggested to be as high as 60%.<sup>21</sup> For many adults, the finding of spinal deformity may be incidental and require only education and follow-up; however, for others it can produce pain and disability that may warrant consideration of surgical treatment.<sup>10,13</sup> In contrast to adolescent idiopathic scoliosis, for which radiographical findings (e.g., coronal Cobb angle) typically guide treatment decisions, the most important factors for the management of adults with spinal deformity are pain and disability.<sup>7,22</sup> Recent studies have suggested the potential benefits of surgical treatment for ASD;<sup>11–13,23–25</sup> however, optimal treatment approaches based on specific deformity characteristics have not been well defined. These efforts, in large part, have been hampered by the lack of an accepted classification system with fundamental clinical relevance and systematic validation based on outcomes by specific categories. The recently reported SRS-Schwab classification was designed on the basis of radiographical parameters with the most clinical relevance, and this study provides a critical clinical validation of this system based on a large, multicenter prospective study.

Both operative and nonoperative patients were included in this analysis, enabling assessment of the clinical validity of the classification system not only for patients electing for operative treatment, but also for those who chose to pursue nonoperative management. Full 1-year follow-up was obtained for patients enrolled in this study, a length of time that should be sufficient for detection of changes in disability and overall HRQOL resulting from either operative or nonoperative treatment approaches.<sup>26,27</sup> At baseline, the operatively treated patient group had significantly greater disability and poorer HRQOL, a finding consistent with previous reports comparing operative and nonoperative ASD treatment groups.<sup>10–12,28</sup> Consistent with their poorer HRQOL scores, the operatively treated patient group also had significantly greater baseline severity of deformity than the nonoperatively treated patient group, and this was reflected by worse scores for all 3 SRS-Schwab classification modifiers.

Compared with baseline scores, at 1-year follow-up, the operative treatment group had significant improvement in all measures of HRQOL assessed, reaching at least MCID thresholds for all outcomes scores. This contrasts with the nonoperative treatment group, which did not demonstrate significant change in HRQOL from baseline to 1-year follow-up that reached MCID for any of the measures with reported MCID values. These findings add further support to previous studies that have documented the potential for surgical treatment to improve HRQOL in adults with spinal deformity, and the general lack of nonoperative measures to result in improvement of HRQOL.<sup>11,12,24</sup>

Favorable changes in the SRS-Schwab PT, SVA, and PI-LL mismatch modifier grades were found to be associated with significant changes in HRQOL measures, demonstrating clinical relevance and sensitivity of the classification system.

Strengths of this study include the prospective design and inclusion of both operatively and nonoperatively treated patients. All radiographical measures were performed at a single center using standardized image analysis software to minimize potential variation in technique. In addition, the multicenter design enhances the generalizability of the findings. Limitations of this study include the lack of a standardized protocol for nonoperative treatment; however, all patients treated nonoperatively continued to be followed clinically and were offered and encouraged to pursue nonoperative measures as desired. In addition, only limited data exist regarding MCID values for HRQOL measures specifically for ASD, and it is possible that with future study the values used in this study will be further refined.

## CONCLUSION

The SRS-Schwab classification provides a validated language to describe and categorize ASD and has significant association with HRQOL measures. This study demonstrates that the classification modifiers are responsive to changes in disease state and reflect significant changes in patient-reported outcomes whether surgical or nonoperative care was applied.

## ➤ Key Points

- ❑ The SRS-Schwab classification is a validated classification system for ASD that includes a curve type descriptor and 3 sagittal spinopelvic modifiers (SVA, PT, and PI-LL mismatch).
- ❑ Changes in each of the classification system modifiers at 1-year follow-up were associated with significant changes in multiple standardized measures of HRQOL.
- ❑ Patients with improvement of PT, SVA, or PI-LL modifiers were significantly more likely to achieve MCID for ODI, SF-36 PCS (SVA and PI-LL only), SRS activity, and SRS pain (PI-LL only).
- ❑ This study demonstrates that the SRS-Schwab classification system modifiers are responsive to changes in disease state and reflect significant changes in patient-reported outcomes.

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