

## Younger Patients Are Differentially Affected by Stiffness-Related Disability Following Adult Spinal Deformity Surgery

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■ **OBJECTIVE:** The Lumbar Stiffness Disability Index (LSDI) assesses impact of lumbar stiffness on activities of daily living. We hypothesized that patients <60 years old would perceive greater lumbar stiffness–related functional limitation following fusion for adult spinal deformity.

■ **METHODS:** Patients completed the LSDI and Scoliosis Research Society 22 Questionnaire, Revised (SRS-22r) preoperatively and at 2 years postoperatively. The primary independent variable was patient age <60 versus ≥60. Multivariable regression analyses were used.

■ **RESULTS:** Analysis included 267 patients. Patients <60 years old (51.3%) and ≥60 years old (48.7%) were evenly represented. In bivariable analysis, patients age <60 exhibited lower LSDI at baseline versus patients age ≥60 (25.7 vs. 35.5,  $\beta = -9.8$ ,  $P < 0.0001$ ), but a directionally smaller difference at 2 years (26.4 vs. 32.3,  $\beta = -5.8$ ,  $P = 0.0147$ ). LSDI was associated with lower SRS-22r total score among both age groups at baseline and 2 years (all  $P < 0.0001$ ); the association was stronger among patients age <60 versus ≥60 at 2 years. LSDI was associated with SRS-22r satisfaction scores at 2 years among patients age <60 ( $P < 0.0001$ ), but not patients age ≥60 ( $P = 0.2250$ ). The difference in SRS-22r satisfaction per unit LSDI between patients <60 years old and ≥60 years old was significant ( $P = 0.0021$ ).

■ **CONCLUSIONS:** Among patients with adult spinal deformity managed operatively, higher LSDI was

associated with inferior SRS-22r total score and satisfaction at 2 years postoperatively. The association between increased LSDI and worse patient-reported outcome measures was greater among patients age <60 versus ≥60. Preoperative counseling is needed for patients age <60 undergoing adult spinal deformity surgery regarding effects that lumbar stiffness may have on postoperative function and satisfaction.

### INTRODUCTION

Adult spinal deformity (ASD) has significant impact on health-related quality of life (HRQOL), with markedly lower HRQOL among patients with ASD compared with patients with other self-reported chronic medical conditions.<sup>1,2</sup> The volume of fusion surgery for ASD in the United States has substantially increased in recent years.<sup>3,4</sup> ASD surgery averages approximately \$72,000 in direct costs, with total average hospital costs reaching approximately \$126,000 at 4-year follow-up.<sup>5,6</sup> The health-related and economic-related impacts of ASD are thus both substantial and growing.<sup>7</sup>

The Lumbar Stiffness Disability Index (LSDI) is a validated measure of lumbar stiffness–related disability.<sup>8–14</sup> Previous investigations observed that the LSDI inversely correlates with lumbar range of motion,<sup>8</sup> is associated with perceived spinal stiffness independent of functional limitations due to pain,<sup>9</sup> is lower among younger patients,<sup>10</sup> and trends higher among

#### Key words

- Adult spinal deformity
- HRQOL
- Lumbar spine stiffness

#### Abbreviations and Acronyms

**ASD:** Adult spinal deformity  
**CCI:** Charlson comorbidity index  
**HRQOL:** Health-related quality of life  
**LSDI:** Lumbar Stiffness Disability Index  
**SRS-22r:** Scoliosis Research Society 22 Questionnaire, Revised  
**SVA:** Sagittal vertical axis

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Citation: *World Neurosurg.* (2019).  
<https://doi.org/10.1016/j.wneu.2019.08.169>

Journal homepage: [www.journals.elsevier.com/world-neurosurgery](http://www.journals.elsevier.com/world-neurosurgery)

Available online: [www.sciencedirect.com](http://www.sciencedirect.com)

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patients undergoing longer fusions.<sup>11</sup> However, a recent study by Hart et al.<sup>13</sup> observed no association between LSDI and Scoliosis Research Society 22 Questionnaire, Revised (SRS-22r) satisfaction with management score among patients with ASD at 2 years postoperatively.<sup>13</sup>

Similar to other HRQOL metrics, the LSDI is inherently subjective and may therefore be influenced by patients' expectations and goals regarding their quality of life. A study of 881 patients undergoing total joint replacement observed that patients who fulfilled their preintervention expectations for treatment exhibited superior increases in HRQOL.<sup>15</sup> Another study of patients with colorectal cancer found that patients <65 years old exhibited poor postoperative HRQOL; the authors hypothesized that this may be attributed to "unrealistically high expectations" among younger patients for posttreatment improvement.<sup>16</sup> We hypothesized that patients <60 years old would exhibit higher lumbar stiffness-related disability at 2 years postoperatively following ASD surgery and that LSDI would be more strongly associated with SRS-22r satisfaction and total scores among patients <60 years old than among patients  $\geq$ 60 years old.

## MATERIALS AND METHODS

### Patient Sample

This study used a prospective, multicenter database of patients who underwent ASD surgery. Patients who met inclusion criteria were >18 years old with coronal curve of  $\geq 20^\circ$ , a sagittal vertebral axis (SVA) of  $\geq 5$  cm, or pelvic tilt of  $>25^\circ$ ; with deformity not attributable to acute trauma, tumor, infection, or neuropathic diagnosis; and with complete 2-year follow-up data.

### Outcome Measures

The primary outcome measures were the LSDI, the SRS-22r satisfaction score, and the SRS-22r total score.

### Independent Variables

The primary independent variable in this study was patient age, grouped into <60 and  $\geq$ 60 years. LSDI was also used as an independent variable in analyses of differences in SRS-22r total and satisfaction scores. Multivariable analyses also included the following potential confounding variables: sex, body mass index, Charlson comorbidity index (CCI), number of posterior levels fused, history of prior fusion at baseline, revision fusion before 2-year follow-up, distal fusion to the sacrum and pelvis, SVA, and maximum coronal Cobb angle.

### Statistical Analysis

Descriptive statistics were generated. Linear regression was used to assess the relationship between LSDI and patient age at baseline and 2 years postoperatively. Poisson regression was used in analyses of SRS-22r satisfaction and total scores at baseline and 2 years postoperatively. The primary independent variables in these analyses were age group, LSDI, and their interaction. A linear combination of regression coefficients for LSDI and the interaction term was generated to evaluate the change in SRS-22r total and satisfaction scores per unit of LSDI for the nonreference age group. Per Cameron and Trivedi,<sup>17</sup> robust standard errors were generated for Poisson regression coefficients. Both bivariable

and multivariable analyses were performed, with the latter adjusting for potential confounding variables. Among patients <60 years old, interactions between covariates and LSDI were tested in models for 2-year SRS-22r satisfaction score. Operative variables were excluded from multivariable analyses of baseline LSDI and SRS-22r satisfaction score. Patients missing baseline or follow-up data for LSDI, SRS-22r satisfaction score, or age were excluded. Variable tolerance in a linear regression model was used to screen for multicollinearity, with no concerning values noted. Plots of fitted versus actual values for Poisson regression were created in R version 3.5.0 (R Foundation for Statistical Computing, Vienna, Austria) with the ggplot and ggpubr packages, and fitted values by LSDI and age group were generated using coefficients from multivariable regression analysis. All other analysis was completed using SAS 9.4 (SAS Institute, Cary, North Carolina, USA). Cases with missing data were omitted on a listwise basis. Statistical significance was defined as  $P < 0.05$ .

## RESULTS

### Descriptive Statistics

A total of 67 patients were analyzed; 51.3% ( $n = 137$ ) of patients were <60 years old. The majority of patients were women (81.7%;  $n = 218$ ). Most patients were American Society of Anesthesiologists grade II (50.6%;  $n = 130$ ) and III (38.5%;  $n = 99$ ) and underwent fusion to the pelvis (76.4%;  $n = 201$ ). Compared with patients  $\geq$ 60 years old, patients <60 years old exhibited lower CCI (1.1 vs. 2.2,  $P < 0.0001$ ), were more likely female (88.3% vs. 74.6%,  $P = 0.0038$ ), exhibited generally lower American Society of Anesthesiologists classification ( $P < 0.0001$ ), and were less likely to undergo fusion to the pelvis (63.0% vs. 90.6%,  $P < 0.0001$ ). At baseline, patients <60 years old exhibited lower SVA (38.7 mm vs. 84.2 mm,  $P < 0.0001$ ) and higher maximum coronal Cobb angle ( $50.1^\circ$  vs.  $35.3^\circ$ ,  $P < 0.0001$ ) (Table 1). The mean baseline LSDI was 30.5 (SD 18.0) and 2-year LSDI was 29.3 (SD 19.6) (Table 2).

### Association Between Age Group and LSDI

Bivariable analyses indicated significantly lower LSDI among patients <60 years old versus  $\geq$ 60 years old both at baseline (25.7 vs. 35.5,  $\beta -9.8$ ,  $P < 0.0001$ ) and at 2 years postoperatively (26.4 vs. 32.3,  $\beta -5.8$ ,  $P = 0.0147$ ) (Table 3).

### Interaction of Age Group and LSDI: SRS-22r Total Score

After adjusting for potential confounding factors, LSDI was associated with lower SRS-22r total score among both patients <60 years old and  $\geq$ 60 years old, at both baseline and at 2 years (all  $P < 0.0001$ ). The change in SRS-22r total score per unit LSDI was greater among patients <60 years old versus patients  $\geq$ 60 years old at 2 years postoperatively ( $P = 0.0008$ ); however, no difference was observed between the 2 age groups at baseline ( $P = 0.8073$ ) (Figure 1 and Supplemental Tables S1 and S2). Notably, SVA was inversely associated with lower SRS-22r total score at baseline ( $P = 0.0226$ ) and 2 years postoperatively ( $P = 0.0257$ ). No other variables were statistically significant in multivariable regression analysis.

**Table 1.** Descriptive Statistics (Patient Characteristics)

Variable	All Patients*	Age <60†	Age ≥60†	P Value
BMI	27.2 (5.8)	26.6	27.8	0.0741
CCI	1.6 (1.7)	1.1	2.2	<0.0001
Levels fused	11.0 (4.3)	11.1	10.8	0.3775
Baseline alignment				
SVA, mm	60.7 (76.5)	38.7	84.2	<0.0001
Maximum coronal Cobb angle, °	42.8 (20.5)	50.1	35.3	<0.0001
2-Year alignment				
SVA, mm	29.6 (55.2)	18.9	40.9	0.0002
Maximum coronal Cobb angle, °	22.7 (16.0)	25.4	19.9	0.0002
Age				
<60	137 (51.3%)	—	—	
≥60	130 (48.7%)	—	—	
Sex				
Male	49 (18.4%)	11.7%	25.4%	0.0038
Female	218 (81.7%)	88.3%	74.6%	
ASA grade				
I	25 (9.7%)	14.7%	4.7%	<0.0001
II	130 (50.6%)	58.9%	42.2%	
III	99 (38.5%)	25.6%	51.6%	
IV	3 (1.2%)	0.8%	1.6%	
Missing	10 (—)			
Pelvic fusion				
No	62 (23.6%)	37.0%	9.4%	<0.0001
Yes	201 (76.4%)	63.0%	90.6%	
Missing	4 (—)			
Prior fusion at baseline				
No	177 (66.3%)	71.5%	60.8%	0.0629
Yes	90 (33.7%)	28.5%	39.2%	
Revision surgery before 2-year follow-up				
No	222 (83.2%)	80.3%	86.2%	0.2009
Yes	45 (16.9%)	19.7%	13.9%	

BMI, body mass index; CCI, Charlson comorbidity index; SVA, sagittal vertical axis; ASA, American Society of Anesthesiologists.  
 \*Values are mean (SD) or number (%).  
 †Values are mean or %.

**Interaction of Age Group and LSDI: SRS-22r Satisfaction Score**

LSDI was not significantly associated with SRS-22r satisfaction score at baseline among either patients <60 years old or ≥60 years old (all  $P > 0.05$ ). LSDI was inversely associated with SRS-22r satisfaction score among patients <60 years old at 2 years

**Table 2.** Descriptive Statistics (Outcomes)

HRQOL	Mean (SD)
Baseline	
LSDI	30.5 (18.0)
SRS-22r satisfaction	2.8 (1.1)
SRS-22r total	2.8 (0.7)
2 Years	
LSDI	29.3 (19.6)
SRS-22r satisfaction	4.2 (1.0)
SRS-22r total	3.7 (0.8)

HRQOL, health-related quality of life; LSDI, Lumbar Stiffness Disability Index; SRS-22r, Scoliosis Research Society 22 Questionnaire, Revised.

postoperatively ( $P < 0.0001$ ), but not among patients ≥60 years old ( $P = 0.2250$ ); the difference in association between the 2 age groups was statistically significant ( $P = 0.0021$ ) (Figure 2 and Supplemental Tables S1 and S2). Notably, maximum coronal Cobb angle was inversely associated with baseline SRS-22r satisfaction score ( $P = 0.0038$ ). Modeling 2-year SRS-22r satisfaction score, a significant interaction between LSDI and baseline CCI among patients <60 years old was observed ( $\beta_{\text{LSDI-2Y}} = -0.0073$ ,  $P < 0.0001$ ;  $\beta_{\text{CCI}} = -0.0322$ ,  $P = 0.1699$ ;  $\beta_{\text{LSDI-2Y*CCI}} = 0.0013$ ,  $P = 0.0257$ ), indicating an inverse relationship between LSDI and satisfaction primarily at lower levels of CCI. Case examples illustrating these dynamics are depicted in Figure 3.

**DISCUSSION**

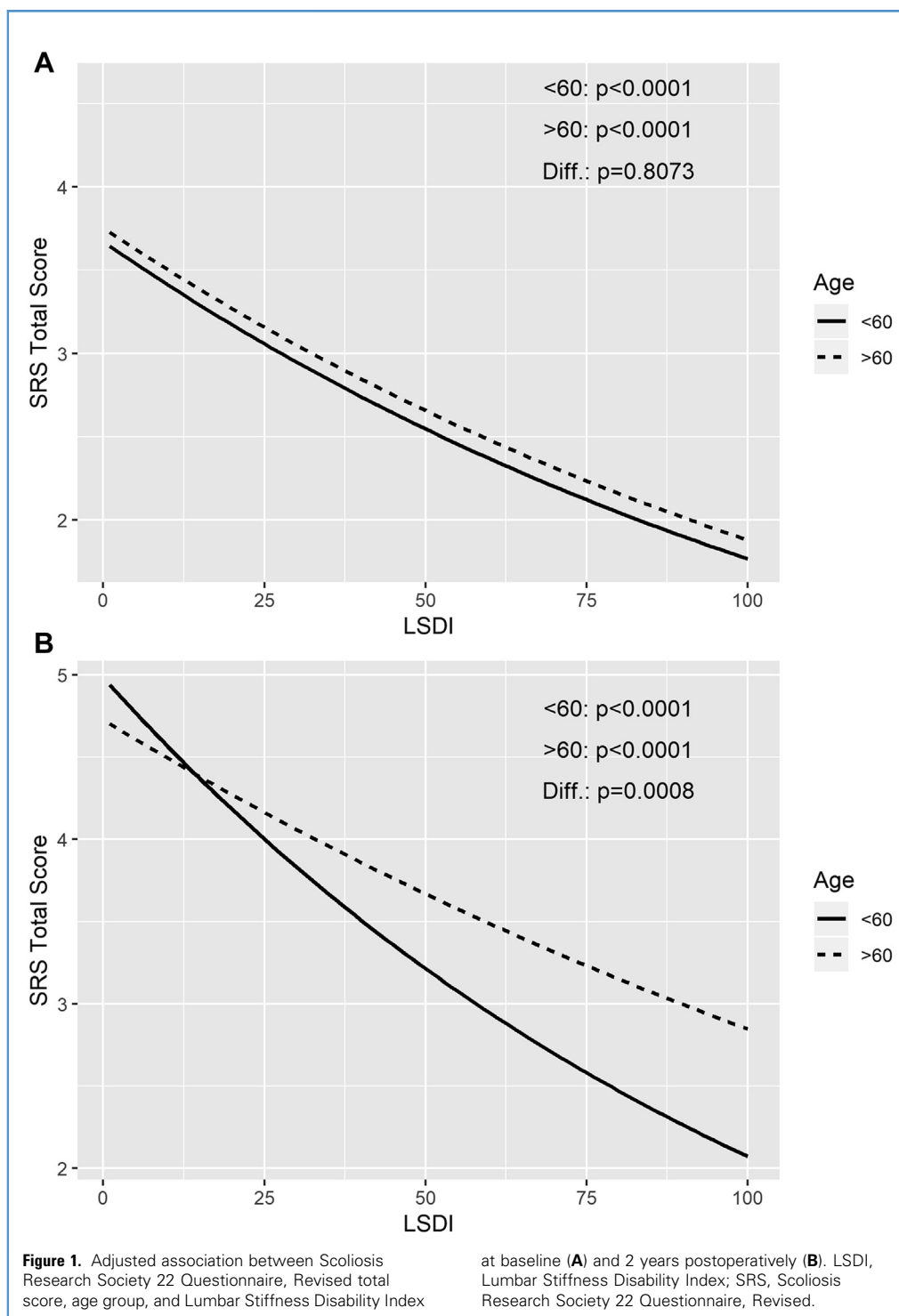
Among patients with ASD managed operatively, higher LSDI was associated with inferior SRS-22r total score and satisfaction at 2 years postoperatively. The association between increased LSDI and worse patient-reported outcome measures was greater among patients <60 years old versus ≥60 years old, particularly patients with low baseline CCI. These findings highlight the differential and more detrimental effects of postoperative stiffness in patients <60 years old with ASD.

Consistent with previous studies, we observed that patients <60 years old with ASD exhibited lower lumbar-related disability at

**Table 3.** Association Between Age Group and Lumbar Stiffness Disability Index

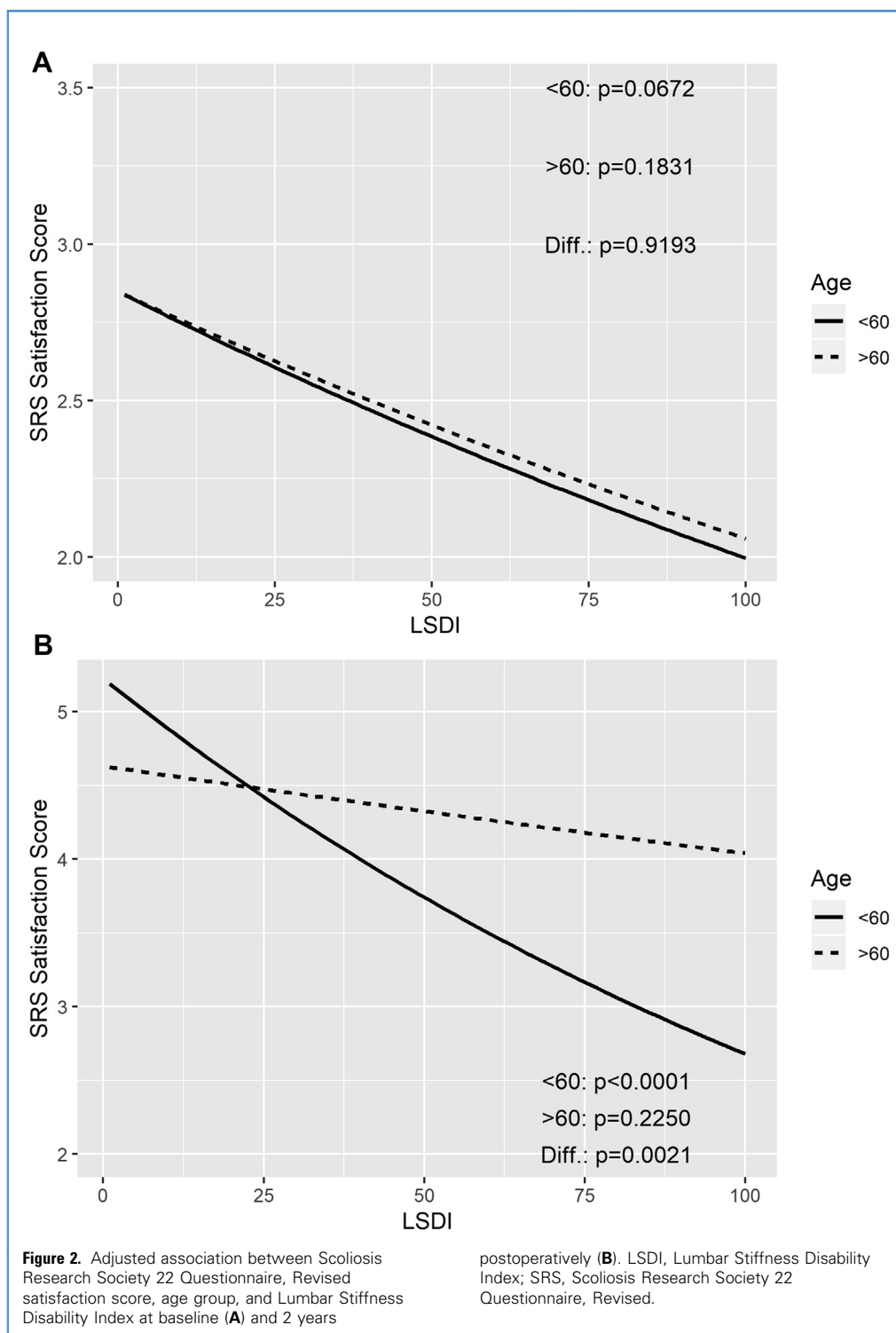
Dependent Variable	Bivariable				
	Age <60	Age ≥60	$\beta$	SE	P Value
Baseline LSDI	25.7	35.5	-9.8	2.1	<0.0001
2-Year LSDI	26.4	32.3	-5.8	2.4	0.0147
$\Delta$ LSDI	0.8	-3.2	4.0	2.4	0.0963

LSDI, Lumbar Stiffness Disability Index.



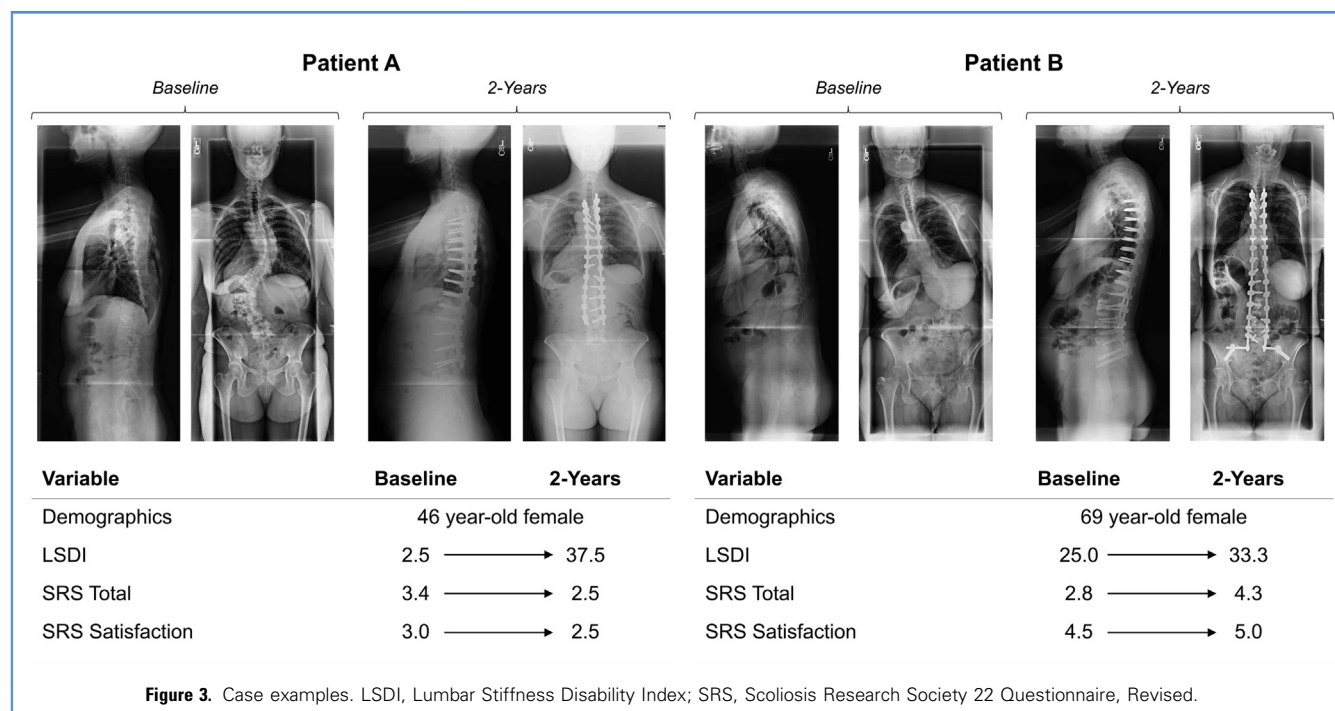
baseline, but a directionally smaller difference between the two groups at 2 years postoperatively.<sup>10</sup> This observation resulted from a trend toward decreased LSDI from baseline among patients  $\geq 60$  years old coupled with trending increased LSDI from baseline

among patients  $< 60$  years old. It is possible that younger patients may perceive less benefit from surgery regarding stiffness-related disability than older patients. Higher baseline stiffness among older patients may allow for greater postoperative



improvement than among younger patients. If so, future investigations should be undertaken to more precisely determine the functional domains along which younger patients experience improvement following surgery. Importantly, given mixed results

in the literature, this hypothesis assumes that the relationship between age and postoperative gains in HRQOL are highly variable by procedure.<sup>18-20</sup> It is also highly possible that this discrepancy results from differing preoperative expectations



regarding postoperative improvement in stiffness. This is likely related to our observation that younger patients were less likely to undergo fusion to the pelvis compared with older patients. We also observed a nonsignificant trend toward lower rates of previous fusion among younger patients. Arthrodesis for ASD trades disease-related stiffness for surgery-related stiffness, and younger patients may have higher expectations regarding the impact of the latter on activities of daily living. These hypotheses are not mutually exclusive, and future studies should be conducted to discover the importance of each in determining postoperative HRQOL improvements among younger patients.

Patient satisfaction with management was inversely associated with LSDI only among younger patients at 2 years postoperatively. On subanalysis, this inverse relationship manifested primarily among younger patients with low baseline CCI scores. These results suggest that satisfaction with management among younger patients is more influenced by perceived stiffness-related disability than it is among older patients. Such dissatisfaction may be particularly pronounced among younger patients with low baseline comorbidity burden. Previous studies have produced mixed results on the association between patient age and postoperative satisfaction.<sup>21-24</sup> Bourne et al.<sup>21</sup> examined patient satisfaction among 1703 patients following primary total knee replacement and observed that increasing age was associated with decreased satisfaction. Husted et al.<sup>22</sup> observed increasing satisfaction with increasing age among a cohort of 712 patients with total joint replacement. Myles et al.<sup>23</sup> surveyed a broad cohort of surgical patients postoperatively and found that patients <65 years old exhibited lower satisfaction rates than patients ≥65 years old. Alderman et al.<sup>24</sup> found that age was not significantly associated with patient satisfaction following postmastectomy breast

reconstruction. Accordingly, the association between patient age and postoperative satisfaction is likely highly variable by procedure. None of these studies, however, analyzed age-related differences in the association between satisfaction and other independent variables. Our findings call for additional research on the relative influence of various functional metrics on HRQOL across patient demographic categories.

The lack of preoperative difference between age groups for the association between LSDI and SRS-22r satisfaction score suggests that younger patients may perceive baseline disease-related stiffness differently than postoperative arthrodesis-related stiffness. Previous studies have shown a relationship between surgical patient satisfaction and information provided at admission, preoperative expectations, and pain management.<sup>25-27</sup> Satisfaction with management is important for both patients and health systems, particularly as pay-for-performance reimbursement schemes gain traction.<sup>28</sup> Future studies on the relationship between stiffness-related disability and surgical satisfaction are warranted, particularly with regard to preoperative management of patient expectations.

The association between LSDI and SRS-22r total score was significantly greater among patients <60 years old at 2 years postoperatively but not at baseline. Accordingly, postoperative stiffness-related disability may be particularly influential on overall HRQOL among younger patients. Patient expectations, satisfaction with management, and overall HRQOL are distinct yet interrelated concepts and should be considered holistically. Taken together, these findings strongly suggest that younger patients may have especially high expectations for their postoperative stiffness-related disability; these expectations may influence not only satisfaction with management but also overall perceived

quality of life. Additional research on best practices for preoperative education of patients with ASD is warranted.

This study had several potential limitations. The various HRQOL metrics analyzed in this study are likely interrelated, limiting conclusions regarding causation. Additionally, this analysis was performed on a diverse cohort of patients, including patients undergoing revision surgery as well as both pelvic and nonpelvic fixation. This approach was deemed reasonable for both statistical (i.e., increased sample size to avoid type II error) and conceptual (e.g., the disabling effects of lumbar stiffness should be captured by the LSDI regardless of revision status) reasons. Whereas our multivariable approach attempted to control for potential confounding factors, the use of a diverse cohort may increase the possibility of unknown confounders.

## REFERENCES

- Pellisè F, Vila-Casademunt A, Ferrer M, et al. Impact on health related quality of life of adult spinal deformity (ASD) compared with other chronic conditions. *Eur Spine J*. 2015;24:3-11.
- Fu KMG, 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.
- Rajae SS, Bae HW, Kanim LE, Delamarter RB. Spinal fusion in the United States: analysis of trends from 1998 to 2008. *Spine (Phila Pa 1976)*. 2012;37:67-76.
- Deyo RA, Gray DT, Kreuter W, Mirza S, Martin BI. United States trends in lumbar fusion surgery for degenerative conditions. *Spine (Phila Pa 1976)*. 2005;30:1441-1445.
- McCarthy IM, Hostin RA, O'Brien MF, et al. Analysis of the direct cost of surgery for four diagnostic categories of adult spinal deformity. *Spine J*. 2013;13:1843-1848.
- McCarthy IM, Hostin RA, Ames CP, et al. Total hospital costs of surgical treatment for adult spinal deformity: an extended follow-up study. *Spine J*. 2014;14:2326-2333.
- Martin BI, Deyo RA, Mirza SK, et al. Expenditures and health status among adults with back and neck problems. *JAMA*. 2008;299:656-664.
- Hart RA, Gundle KR, Pro SL, Marshall LM. Lumbar Stiffness Disability Index: pilot testing of consistency, reliability, and validity. *Spine J*. 2013;13:157-161.
- Hart RA, Pro SL, Gundle KR, Marshall LM. Lumbar stiffness as a collateral outcome of spinal arthrodesis: a preliminary clinical study. *Spine J*. 2013;13:150-156.
- Daniels AH, Smith JS, Hiratzka J, et al. Functional limitations due to lumbar stiffness in adults with and without spinal deformity. *Spine (Phila Pa 1976)*. 2015;40:1599-1604.
- Hart RA, Marshall LM, Hiratzka SL, Kane MS, Volpi J, Hiratzka JR. Functional limitations due to

## CONCLUSIONS

This study analyzed the relationship between age, LSDI, SRS-22r satisfaction score, and SRS-22r total score among patients who underwent ASD surgery. Patient satisfaction and total SRS-22r score were markedly more associated with LSDI among younger versus older patients. The inverse relationship between LSDI and satisfaction was particularly pronounced among younger patients with low baseline comorbidity burden. Stiffness-related disability may therefore be more influential on postoperative outcomes among relatively healthy patients <60 years old. Accordingly, younger patients may particularly benefit from dedicated preoperative patient education regarding stiffness after arthrodesis. Surgical approaches designed to optimize trade-offs between lumbar stiffness and functional improvement should also be considered in younger patients with few comorbidities.

stiffness as a collateral impact of instrumented arthrodesis of the lumbar spine. *Spine (Phila Pa 1976)*. 2014;39:E1468-E1474.

- Sciubba DM, Scheer JK, Smith JS, et al. Which daily functions are most affected by stiffness following total lumbar fusion. *Spine (Phila Pa 1976)*. 2015;40:1338-1344.
- Hart RA, Hiratzka J, Kane MS, et al. Stiffness after pan-lumbar arthrodesis for adult spinal deformity does not significantly impact patient functional status or satisfaction irrespective of proximal endpoint. *Spine (Phila Pa 1976)*. 2017;42:1151-1157.
- Daniels AH, Koller H, Hiratzka SL, et al. Selecting caudal fusion levels: 2 year functional and stiffness outcomes with matched pairs analysis in multi-level fusion to L5 versus S1. *Eur Spine J*. 2017;26:1645-1651.
- Gonzalez Sáenz de Tejada M, Escobar A, Herrera C, García L, Aizpuru F, Sarasqueta C. Patient expectations and health-related quality of life outcomes following total joint replacement. *Value Health*. 2010;13:447-454.
- Wilson T, Alexander D. Clinical and non-clinical factors influencing postoperative health-related quality of life in patients with colorectal cancer. *Br J Surg*. 2008;95:1408-1415.
- Cameron AC, Trivedi PK. *Microeconometrics with STATA*. College Station, TX: StataCorp LP; 2009.
- Jansson K-Å, Nemeth G, Granath F, Jönsson B, Blomqvist P. Health-related quality of life in patients before and after surgery for a herniated lumbar disc. *Bone Joint J*. 2005;87:959-964.
- Jones C, Voaklander DC, Johnston DC, Suarez-Almazor ME. The effect of age on pain, function, and quality of life after total hip and knee arthroplasty. *Arch Intern Med*. 2001;161:454-460.
- Jansson K-Å, Granath F. Health-related quality of life (EQ-5D) before and after orthopedic surgery. *Acta Orthop*. 2011;82:82-89.
- Bourne RB, Chesworth BM, Davis AM, Mahomed NN, Charron KD. Patient satisfaction after total knee arthroplasty: who is satisfied and who is not? *Clin Orthop Relat Res*. 2010;468:57-63.

- Husted H, Holm G, Jacobsen S. Predictors of length of stay and patient satisfaction after hip and knee replacement surgery: fast-track experience in 712 patients. *Acta Orthop*. 2008;79:168-173.
- Myles P, Williams D, Hendrata M, Anderson H, Weeks A. Patient satisfaction after anaesthesia and surgery: results of a prospective survey of 10,811 patients. *Br J Anaesth*. 2000;84:6-10.
- Alderman AK, Wilkins EG, Lowery JC, Kim M, Davis JA. Determinants of patient satisfaction in postmastectomy breast reconstruction. *Plast Reconstr Surg*. 2000;106:769-776.
- Mira JJ, Tomas O, Virtudes-Perez M, Nebot C, Rodriguez-Marin J. Predictors of patient satisfaction in surgery. *Surgery*. 2009;145:536-541.
- Hamilton D, Lane JV, Gaston P, et al. What determines patient satisfaction with surgery? A prospective cohort study of 4709 patients following total joint replacement. *BMJ Open*. 2013;3:e002525.
- Younger ASE, Wing KJ, Glazebrook M, et al. Patient expectation and satisfaction as measures of operative outcome in end-stage ankle arthritis: a prospective cohort study of total ankle replacement versus ankle fusion. *Foot Ankle Int*. 2015;36:123-134.
- Morris BJ, Jahangir AA, Sethi MK. Patient satisfaction: an emerging health policy issue. *AAOS Now*. 2013;7:29.

*Conflict of interest statement: The International Spine Study Group is funded through research grants from DePuy Synthes Spine, K2M, NuVasive, Biomet, Orthofix, and Allosource. The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.*

Received 26 June 2019; accepted 22 August 2019

Citation: *World Neurosurg*. (2019).

<https://doi.org/10.1016/j.wneu.2019.08.169>

Journal homepage: [www.journals.elsevier.com/world-neurosurgery](http://www.journals.elsevier.com/world-neurosurgery)

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## SUPPLEMENTARY DATA

**Supplemental Table S1.** Association Between Age Group, Lumbar Stiffness Disability Index, and Scoliosis Research Society 22 Questionnaire, Revised (Unadjusted)

Age Group	$\Delta$	SE	P Value
Baseline			
SRS-22r total			
≥60	-0.008	0.001	<0.0001
<60	-0.009	0.001	<0.0001
Difference	—	—	0.4923
SRS-22r satisfaction			
≥60	-0.002	0.002	0.3812
<60	-0.002	0.002	0.2814
Difference	—	—	0.9266
2-Year			
SRS-22r total			
≥60	-0.006	0.001	<0.0001
<60	-0.009	0.001	<0.0001
Difference	—	—	0.0014
SRS-22r satisfaction			
≥60	-0.002	0.001	0.0426
<60	-0.006	0.001	<0.0001
Difference	—	—	0.0108

$\Delta$  column represents the change in log count of SRS-22r total and satisfaction scores per unit change of Lumbar Stiffness Disability Index among patients <60 and ≥60 years of age and the difference between the 2 groups.

SRS-22r, Scoliosis Research Society 22 Questionnaire, Revised.

**Supplemental Table S2.** Association Between Age Group, Lumbar Stiffness Disability Index, and Scoliosis Research Society 22 Questionnaire, Revised (Multivariable)

Age Group	$\Delta$	SE	P Value
Baseline			
SRS-22r total			
≥60	-0.007	0.001	<0.0001
<60	-0.007	0.001	<0.0001
Difference	—	—	0.8073
SRS-22r satisfaction			
≥60	-0.003	0.002	0.1831
<60	-0.004	0.002	0.0672
Difference	—	—	0.9193
2-Year			
SRS-22r total			
≥60	-0.005	0.001	<0.0001
<60	-0.009	0.001	<0.0001
Difference	—	—	0.0008
SRS-22r satisfaction			
≥60	-0.001	0.001	0.2250
<60	-0.007	0.001	<0.0001
Difference	—	—	0.0021

$\Delta$  column represents the change in log count of SRS-22r total and satisfaction scores per unit change of Lumbar Stiffness Disability Index among patients <60 and ≥60 years of age and the difference between the 2 groups.

SRS-22r, Scoliosis Research Society 22 Questionnaire, Revised.