Spine

SPINE Volume 40, Number 20, pp 1599-1604

DEFORMITY

Functional Limitations Due to Lumbar Stiffness in Adults With and Without Spinal Deformity

Alan H. Daniels, MD,* Justin S. Smith, MD, PhD,† Jayme Hiratzka, MD,‡ Christopher P. Ames, MD,§ Shay Bess, MD,¶ Christopher I. Shaffrey, MD,† Frank J. Schwab, MD,‖ Virginie Lafage, PhD,‖ Eric O. Klineberg, MD,** Doug Burton, MD,†† Greg M. Mundis, MD,‡‡ Breton Line, BS,¶ Robert A. Hart, MD,‡ and the International Spine Study Group (ISSG)§§

Study Design. Cross-sectional analysis.

Objective. To compare Lumbar Stiffness Disability Index (LSDI) scores between asymptomatic adults and patients with spinal deformity.

Summary of Background Data. The LSDI was designed and validated as a tool to assess functional impacts of lumbar spine stiffness and diminished spinal flexibility. Baseline disability levels of patients with adult spinal deformity (ASD) are high as measured by multiple validated outcome tools. Baseline lumbar stiffness-related disability has not been assessed in adults with and without spinal deformity.

Methods. The LSDI and Scoliosis Research Society-22r (SRS-22r) were submitted to a group of asymptomatic adult volunteers. Additionally, a multicenter cross-sectional cohort analysis of patients with ASD from 10 centers was conducted. Baseline LSDI and SRS-22r were completed for both operatively and nonoperatively treated patients with deformity.

Results. The LSDI was completed by 176 asymptomatic volunteers and 693 patients with ASD. Mean LSDI score for asymptomatic volunteers was 3.4 +/− 6.3 out of a maximum score of 100, with significant correlation between increasing age and higher (worse) LSDI score ($r = 0.30$, $P = 0.0001$). Of the patients with spinal deformity undergoing analysis, 301 subsequently underwent surgery and 392 were subsequently treated nonoperatively. Operative patients had significantly higher preoperative LSDI scores than both nonoperative patients and asymptomatic volunteers (29.9 *vs.* 17.3 *vs.* 3.4, $P < 0.0001$ for both). For patients with ASD, significant correlations were found between LSDI and SRS-22 Pain and Function subscales ($r = -0.75$ and -0.76, respectively; $P < 0.0001$ for both).

Conclusion. LSDI scores are low among asymptomatic volunteers, although stiffness-related disability increases with increasing age. Patients with ASD report substantial stiffness-related disability even prior to surgical fusion. Stiffness-related disability correlates with pain- and function-related disability measures among patients with spinal deformity.

Key words: adult spinal deformity, LSDI, lumbar spine, spine fusion, adverse outcomes, collateral outcomes, spinal stiffness.

Level of Evidence: 1

Spine 2015;40:1599–1604

From the *Department of Orthopaedics, Warren Alpert School of Medicine, Brown University, Providence, RI; †Department of Neurosurgery, University of Virginia, Charlottesville, VA; ‡Department of Orthopedics and Rehabilitation, Oregon Health and Science University, Portland, OR; §Department of Neurosurgery, University of California-San Francisco Medical Center, San Francisco, CA; ¶Department of Orthopaedic Surgery, Rocky Mountain Hospital for Children, Denver, CO; ‖Department of Orthopaedic Surgery, NYU Hospital for Joint Diseases, New York, NY; **Department of Orthopaedic Surgery, University of California–Davis, Sacramento, CA; ††Department of Orthopaedic Surgery, University of Kansas Medical Center, Kansas City, KS; ‡‡San Diego Center for Spinal Disorders, La Jolla, CA; and §§International Spine Study Group (ISSG).

Acknowledgment date: September 23, 2014. Revision date: April 21, 2015. Acceptance date: May 11, 2015.

The manuscript submitted does not contain information about medical device(s)/drug(s).

Depuy-Synthes funds were received in support of this work.

Relevant financial activities outside the submitted work: board membership, consultancy, employment, expert testimony, grants, payment for lectures, patents, royalties, stocks, payment for development of educational presentations, travel/accommodations/meeting expenses.

Address correspondence and reprint requests to Robert A. Hart, MD, Department of Orthopaedics and Rehabilitation, Oregon Health and Sciences University, 3181 S.W. Sam Jackson Park Road, OP31 Portland, OR 97239-3098; E-mail: hartro@ohsu.edu

DOI: 10.1097/BRS.0000000000001090

Patient-reported outcomes instruments have been widely adopted for clinical research in many medical disciplines as a tool to compare the effectiveness of medical and surgical interventions.[1,2] Outcomes instruments must be proven reliable, standardized, and validated to be useful in clinical practice and research. Several general and condition-specific outcome instruments are currently in use for clinical spine research,[3–21] primarily for assessing proposed benefits of surgery on pain, function, and deformity.[3,9,10,12] More recently, the Lumbar Stiffness Disability Index (LSDI) has been validated as a tool designed to assess functional limitations due to stiffness and diminished spinal flexibility as distinct from pain and deformity.[21–23]

Understanding the relationship between factors that can be surgically improved (*e.g.*, neurological compression or spinal malalignment) and patients' own reports of their disability level is critical to predicting success after a surgical intervention. Factors known to correlate with high levels of disability

TABLE 1. Lumbar Stiffness Disability Index Questionnaire

Choose the Statement That Best Describes the Effect of Low Back Stiffness on Your Ability to:
1. Bend to your feet to put on your underwear and pants while dressing independently
2. Bend through your waist to put on your socks and shoes
3. Drive a motor vehicle
4. Perform personal hygiene functions after toileting
5. Bend forward to pick up a small object off the floor
6. Get in and out of bed
7. Get in and out of a chair
8. Bathe the lower half of your body
9. Get in and out of an automobile
10. Engage in sexual intercourse
Response Options and Score for Each Item
0 No effect at all
1 Minor effect
2 Significant effect
3 Require assistance
4 Cannot do at all

and to be improved in many patients after surgery for adult spinal degenerative disease and adult spinal deformity (ASD) include leg pain, back pain, and positive sagittal imbalance or hypolordosis of the lumbar spine.[24–27]

In addition to predicting benefits of surgery, an understanding of risks and impacts of adverse surgical effects is also required. One aspect of such an evaluation is knowing expected incidence and clinical effect of complications or unexpected adverse events.[26,28] However, many negative surgical impacts are an expected result of surgery; such effects can be referred to as "collateral adverse effects" or "sequelae." [29,30] Expected impacts of limitations in mobility due to low back stiffness after spinal fusion remain incompletely defined, despite the intended goal of fusion surgery.

The LSDI specifically assesses functional impacts and limitations in performing 10 specific daily activities created by lumbar stiffness (LSDI, Table 1). The psychometric and external validity of the LSDI have recently been demonstrated.[22] Although a preliminary report of LSDI scores in lumbar fusion patients has been made,[21,23] data for asymptomatic individuals and preoperative patient candidates with ASD for spinal fusion have not been reported. Baseline stiffness-related disability has not been assessed in an ASD patient population, despite the fact that such patients often undergo fusions of their entire lumbar spines.

The purpose of this study was to assess stiffness-related disability among asymptomatic volunteers in addition to a cohort of patients with ASD prior to definitive surgical correction. We also sought correlations between LSDI scores and other outcomes instruments.

MATERIALS AND METHODS

This investigation was a cross-sectional study of asymptomatic adults in addition to patients with ASD treated both operatively and nonoperatively at 10 spinal deformity centers. Institutional review board approval was obtained at all participating centers prior to initiating this study.

Asymptomatic Volunteers

Asymptomatic volunteers were recruited via E-mail, with blinded identity of the subjects. Exclusion criteria included a history of spine surgery, back pain, scoliosis, traumatic spine injury, cancer, neurological disease, extremity amputation, or prior hip or knee surgery. The LSDI and Scoliosis Research Society-22r (SRS-22r) instruments were submitted to this group of asymptomatic adult volunteers via an online questionnaire. The LSDI consists of 10 questions and is scored from 0 to 100, with higher scores representing increasing difficulty in performing activities of daily living due to lumbar spine stiffness (Table 1). The SRS-22r consists of 22 questions, with subscale calculations including pain, mental and physical function, and spinal deformity. Lower total and subscale scores on SRS-22r represent a worsened clinical situation, inverse to the LSDI.

Patients With ASD

Patients with ASD who presented to surgical clinics at 10 spine centers across the United States were offered enrollment in the study. Patients with spinal deformity were defined as those with at least one of the following: degenerative or idiopathic scoliosis with a coronal Cobb angle of at least 20°, sagittal vertical axis of greater than 5 cm, pelvic tilt of greater than 25°, or thoracic kyphosis of greater than 60°. Exclusion criteria included a diagnosis of post-traumatic, neuropathic or congenital spinal deformity or age less than 18 at presentation. Patients with a history of prior spinal fusion surgery were offered enrollment if they met the above criteria. Patients entered either an operative (OP) or the nonoperative (NONOP) cohort based on their preference and their surgeons' assessment of their suitability for surgery. LSDI and SRS-22r were completed by all patients with deformity at entry.

Statistical Analysis

Mean LSDI scores (+/− SD) are reported. For both asymptomatic volunteers and patients with ASD, Pearson correlation coefficients of the LSDI score with age and with SRS-22r total score, as well as pain, and function subscales of the SRS-22r were calculated. Pearson correlation coefficients with r values of less than 0.2 were considered weak correlation, 0.2 to 0.4 modest correlation, 04 to 0.6 moderate correlation, 0.6

TABLE 2. Asymptomatic Volunteer and Adult Spinal Deformity Study Population

Age Range (yr)	Asymptomatic Individuals (n)	Nonoperatively Treated Patients With ASD: NONOP (n)	Operatively Treated Patients With ASD: OP (n)
18–27	36	63	36
28–37	66	55	20
38–47	39	56	27
48–57	24	104	94
58–67	11	114	124
Total	176	392	301

ASD indicates adult spinal deformity; NONOP, nonoperative; OP, operative.

to 0.8 moderately strong correlation, and 0.8 to 1.0 strong correlation. The Student *t* test and Tukey-Kramer honest significant difference (HSD) were used to compare LSDI scores among asymptomatic, operative, and nonoperative as well as between revision fusion and primary fusion patients. Statistical significance of all correlations was set at $P < 0.05$, *a priori*.

RESULTS

Asymptomatic Volunteers

176 volunteers completed the LSDI and the SRS-22r (Table 2). The mean age of the cohort was 37.6 years (range 22–66). Mean LSDI score across the entire cohort was 3.4 (SD 6.3) out of a maximum score of 100. There was a modest but statistically significant correlation between increasing age and worsening LSDI score ($r = 0.30$, $P = 0.0001$).

Within the asymptomatic volunteer cohort, Pearson correlation between LSDI score and mean SRS-22r total score was moderate, and reached statistical significance ($r = 0.48$; $P < 0.0001$). Pearson correlation between LSDI score and pain and function subscales of the SRS-22r were also moderate, and statistically significant ($r = 0.41$ and 0.42, respectively; $P < 0.0001$ for both).

ASD Population

A total of 693 patients with ASD were enrolled; 301 patients subsequently underwent surgery (OP) and 392 subsequently were treated nonoperatively (NONOP). Mean age of patients with spinal deformity was 48.7 years (SD 16.8, range 18–67) (Table 2)

Patients with ASD had significantly higher LSDI scores (22.8) compared with asymptomatic individuals (3.4) ($P < 0.0001$). They also exhibited lower SRS 22 Activity, Pain, Self Image, Mental Health, and Total scores compared with asymptomatic individuals ($P < 0.0001$) (Table 3).

OP patients had significantly higher baseline LSDI scores than both NONOP patients and asymptomatic volunteers (29.9 *vs.* 17.3 *vs.* 3.4, respectively; $P < 0.0001$). Similarly, OP patients compared with NONOP patients had significantly worse, SRS-22r Pain scores (2.4 *vs.* 3.3, $P < 0.0001$) and SRS-22r Activity scores (3.0 *vs.* 3.8, $P < 0.0001$). Patients with ASD with prior lumbar fusions had significantly higher LSDI scores than patients who had not previously undergone lumbar spine fusion (35.2 *vs.* 21.1, $P = 0.01$).

Moderately strong correlations with statistical significance were found between LSDI and SRS-22r Pain and Function subscales for the entire cohort of patients with ASD ($r = -0.75$, -0.76, respectively; $P < 0.0001$ for both) (Table 4). When specifically examining patients with ASD without prior lumbar spinal fusion, significant moderately strong correlations were also found between LSDI and SRS-22r Pain and Function subscales ($r = -0.62$, -0.66, respectively; $P < 0.0001$ for both). Similar moderately strong correlations with statistical significance were found between LSDI and SRS-22r Pain and Function subscales ($r = -0.69$, -0.62, respectively; $P < 0.0001$ for both) for patients with ASD with a history of prior lumbar fusion.

LSDI increased with increasing age for each of the 3 cohorts. An age-stratified analysis of LSDI revealed that asymptomatic patients in each age group had significantly lower LSDI compared with patients with ASD ($P < 0.0009$) (Table 5/Figure 1).

TABLE 3. Age and Health-related Quality-of-Life Measures for Asymptomatic Volunteers and Patients With ASD

	Asymptomatic (n = 176)	ASD (n = 693)	*P*
Age	37.6	48.6	<0.0001
LSDI	3.4	22.8	<0.0001
SRS-22—Activity	4.8	3.4	<0.0001
SRS-22—Pain	4.5	2.9	<0.0001
SRS-22—Self-image	4.4	2.9	<0.0001
SRS-22—Mental Health	4.1	3.6	<0.0001
SRS-22—Total	4.4	3.2	<0.0001

ASD indicates adult spinal deformity; LSDI, Lumbar Stiffness Disability Index; SRS-22, Scoliosis Research Society-22.

TABLE 4. Correlation Coefficients Between LSDI and Health-related Quality-of-Life Measures for Patients With ASD

Comparison	Pearson Correlation (r)	*P*
LSDI *vs.* SRS-22—Pain	−0.749	<0.0001
LSDI *vs.* SRS-22—Function	−0.760	<0.0001
LDI *vs.* SRS-22—Mental Health	−0.461	<0.0001
LSDI *vs.* SRS-22—Total	−0.761	<0.0001

LSDI indicates Lumbar Stiffness Disability Index; ASD, adult spinal deformity.

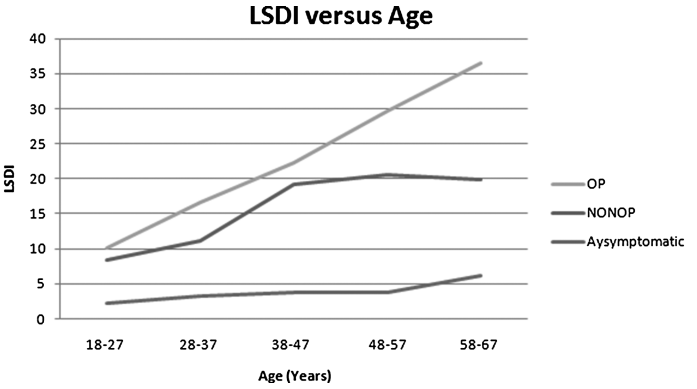

Figure 1. Age-stratified LSDI score for asymptomatic patients and patients with adult spinal deformity without history of lumbar spinal fusion. LSDI indicates Lumbar Stiffness Disability Index; OP, operative; NONOP, nonoperative.

DISCUSSION

This study examined lumbar stiffness-related disability in asymptomatic volunteers and patients with ASD, and presents the first assessment of the LSDI in these populations. We found limitations due to lumbar spine stiffness were low among asymptomatic volunteers, although a statistically significant relationship was noted between worsening LSDI score and advancing age. Patients with ASD, prior to undergoing any surgical intervention report significantly greater stiffness-related disability, which correlated significantly with other measures of disability. Patients with spinal deformity with prior lumbar fusion were found to have higher LSDI scores as compared with patients with spinal deformity without prior lumbar fusion, which is consistent with a previous investigation utilizing the LSDI.[21]

The trend of increasing LSDI with increasing age was consistent across all 3 study cohorts. Similarly, the SRS-22r scores also worsened with increasing age in patients with ASD. This is logical given the fact that LSDI correlates significantly with other measures of disability (SRS-22r, Oswestry Disability Index [ODI], SF-36 scores). In patients with ASD, it is unknown what comes first: pain, deformity, or stiffness. However, patients with ASD even with no history of prior lumbar fusion had significantly higher lumbar stiffness-related disability than asymptomatic volunteers. The substantial stiffness-related disability in patients with ASD even prior to surgical fusion may at least partially explain why many patients with ASD do not readily complain of limitations due to stiffness after long spinal fusions.

Positive correlations between LSDI score and total mean SRS-22r score, as well as the SRS-22r Pain and Function subscales suggest that functional limitations due to lumbar stiffness may occur in tandem with limitations from low back pain. Previous work in nondeformity spinal fusion patients has shown a correlation between LSDI scores and pain impacts, as measured by the ODI.[9,21] This finding makes physiological sense, as patients with low back pain may well avoid aspects of lumbar motion that aggravate their symptoms. The complex relationship between spinal deformity, pain, and stiffness is an important question, which this study does not fully answer. Future study may provide insights into these issues.

It is possible that patients' answers regarding the functional domains of LSDI may be affected by issues other than lumbar stiffness, such as low back pain or hip and knee pathology. Although the stem of each question refers to the impact of low back "stiffness" on function, we ultimately cannot know how a given patient interprets this phrase. However, similar concerns would also apply to other lumbar spine specific outcome instruments such as ODI. In addition, our previous presentation of validation data correlating LSDI scores with lumbar mobility[22] suggests that most patients do interpret the questions appropriately and that LSDI tracks differently than ODI.

While the ultimate role that the LSDI plays in spine outcomes research will depend on the assessment by clinical researchers of its relevance and value, we would not anticipate its routine adoption. Instead, we view LSDI as a directed effort to assess a previously unanswered question in clinical spine research. Development of outcomes tools such as the LSDI represents a potential expansion of outcomes research to include expected results of surgical interventions that negatively impact the patient. Stiffness after lumbar fusion

TABLE 5. Age-stratified LSDI Scores for Asymptomatic Patients and Patients With ASD Without History of Lumbar Spinal Fusion

Age (n)	Asymptomatic LSDI Score (n)	ASD LSDI Score (n)	*P*
18–27 (121)	2.2 (36)	9.0 (85)	0.0009
28–37 (137)	3.2 (66)	12.6 (71)	<0.0001
38–47 (108)	3.8 (39)	20.1 (69)	<0.0001
48–57 (182)	3.8 (24)	24.3 (158)	<0.0001
58–67 (203)	6.1 (11)	27.5 (192)	0.0002
18–67 (751)	3.4 (176)	21.1 (575)	<0.0001

LSDI indicates Lumbar Stiffness Disability Index; ASD, adult spinal deformity.

represents one example of such effects. Postoperative pain and psychological stress represent other unavoidable aspects of surgical care.[29,30] We have referred to negative, but expected, effects of treatment as "collateral outcomes."[21,30]

This study has several limitations. No radiographical data were obtained for the asymptomatic cohort, and it is thus unknown if members of this group may have had spinal degenerative disease or deformity.[31] Additionally, the exclusion criteria for asymptomatic volunteers were more stringent than the study group (*i.e.,* no previous spine, hip, or knee surgery). Both of these effects might lead to bias in the resulting differences in LSDI scores between the 2 cohorts. Furthermore, the mean age of the asymptomatic patients was lower than the ASD cohort. However, we were able to show statistically significant differences in an age-matched analysis (Table 5). Given the relatively small numbers required to generate those differences, it seems that the 2 cohorts do indeed perceive markedly different functional impacts from lumbar stiffness.

This study represents the first effort to objectively measure values for the LSDI in asymptomatic volunteers and patients with ASD. These data may enhance understanding of functional outcome measurements related to spinal stiffness in patients with adult deformity before spinal arthrodesis, and may allow for more informed preoperative counseling to patients indicated for such surgical interventions. Prospective assessments of changes in self-reported stiffness limitations resulting from surgical arthrodesis among patients with ASD would help answer remaining questions regarding expected impacts of fusion on physical function.

➢ Key Points

- ❑ Functional limitations due to lumbar spinal stiffness are mild among asymptomatic volunteers, although stiffness-related disability increases with increasing age.
- ❑ Patients with ASD report substantial stiffness-related disability, even prior to surgical spinal fusion.
- ❑ Stiffness-related disability is correlated with pain- and function-related disability outcome measures among patients with spinal deformity.

References

1. Bombardier C. Outcome assessments in the evaluation of treatment of spinal disorders: summary and general recommendations. *Spine* 2000;25:3100–3.
2. Deyo RA, Battie M, Beurskens AJ, et al. Outcome measures for low back pain research. A proposal for standardized use. *Spine* 1998;23:2003–13.
3. Parent EC, Dang R, Hill D, et al. Score distribution of the Scoliosis Research Society-22 questionnaire in subgroups of patients of all ages with idiopathic scoliosis. *Spine* 2010;35:568–77.
4. Anagnostis C, Gatchel RJ, Mayer TG. The pain disability questionnaire: a new psychometrically sound measure for chronic musculoskeletal disorders. *Spine* 2004;29:2290–302; discussion 2303.
5. Berven S, Deviren V, Demir-Deviren S, et al. Studies in the modified Scoliosis Research Society Outcomes Instrument in adults: validation, reliability, and discriminatory capacity. *Spine* 2003;28:2164–9; discussion 2169.
6. Verma K, Lonner B, Hoashi JS, et al. Demographic factors affect Scoliosis Research Society-22 performance in healthy adolescents: a comparative baseline for adolescents with idiopathic scoliosis. *Spine* 2010;35:2134–9.
7. Haher TR, Gorup JM, Shin TM, et al. Results of the Scoliosis Research Society instrument for evaluation of surgical outcome in adolescent idiopathic scoliosis. A multicenter study of 244 patients. *Spine* 1999;24:1435–40.
8. Daltroy LH, Cats-Baril WL, Katz JN, et al. The North American spine society lumbar spine outcome assessment Instrument: reliability and validity tests. *Spine* 1996;21(6):741–9.
9. Fairbank JC. Use and abuse of Oswestry Disability Index. *Spine* 2007;32:2787–9.
10. Fairbank JC. Comments on "Discriminative validity and responsiveness of the Oswestry disability index among Japanese outpatients with lumbar conditions." *Eur Spine J* 2006;15:1651.
11. Fairbank JC, Pynsent PB. The oswestry disability index. *Spine* 2000;25:2940–52; discussion 2952.
12. Pratt RK, Fairbank JC, Virr A. The reliability of the Shuttle Walking Test, the Swiss Spinal Stenosis Questionnaire, the Oxford Spinal Stenosis Score, and the Oswestry Disability Index in the assessment of patients with lumbar spinal stenosis. *Spine* 2002;27:84–91.
13. Asher M, Min Lai S, Burton D, et al. The reliability and concurrent validity of the Scoliosis Research Society-22 patient questionnaire for idiopathic scoliosis. *Spine* 2003;28:63–9.
14. Asher MA, Min Lai S, Burton DC. Further development and validation of the Scoliosis Research Society (SRS) outcomes instrument. *Spine* 2000;25:2381–6.
15. Bridwell KH, Cats-Baril W, Harrast J, et al. The validity of the SRS-22 instrument in an adult spinal deformity population compared with the Oswestry and SF-12: a study of response distribution, concurrent validity, internal consistency, and reliability. *Spine* 2005;30:455–61.
16. Greenough CG, Fraser RD. Assessment of outcome in patients with low-back pain. *Spine* 1992;17:36–41.
17. Kopec JA, Esdaile JM, Abrahamowicz M, et al. The Quebec Back Pain Disability Scale: conceptualization and development. *J Clin Epidemiol* 1996;49:151–61.
18. Taylor SJ, Taylor AE, Foy MA, et al. Responsiveness of common outcome measures for patients with low back pain. *Spine* 1999;24:1805–12.
19. Albert TJ, Purtill J, Mesa J, et al. Health outcome assessment before and after adult deformity surgery. A prospective study. *Spine* 1995;20:2002–4; discussion p2005.
20. Roland M, Fairbank J. The Roland-Morris Disability Questionnaire and the Oswestry Disability Questionnaire. *Spine* 2000;25:3115–24.
21. Hart RA, Pro SL, Gundle KR, et al. Lumbar stiffness as a collateral outcome of spinal arthrodesis: a preliminary clinical study. *Spine J* 2013;13:150–6.
22. Hart RA, Gundle KR, Pro SL, et al. Lumbar Stiffness Disability Index: pilot testing of consistency, reliability, and validity. *Spine J* 2013;13:157–61.
23. Hart RA, Marshall LM, Hiratzka SL, et al. Functional limitations due to stiffness as a collateral impact of instrumented arthrodesis of the lumbar spine. *Spine* 2014;39:E1468–74.
24. Glassman SD, Bridwell K, Dimar JR, et al. The impact of positive sagittal balance in adult spinal deformity. *Spine* 2005;30:2024–9.
25. Glassman SD, Berven S, Bridwell K, et al. Correlation of radiographic parameters and clinical symptoms in adult scoliosis. *Spine* 2005;30:682–8.
26. Smith JS, Shaffrey CI, Glassman SD, et al. Risk-benefit assessment of surgery for adult scoliosis: an analysis based on patient age. *Spine* 2011;36:817–24.
27. Smith JS, Shaffrey CI, Glassman SD, et al. Clinical and radiographic parameters that distinguish between the best and worst outcomes of scoliosis surgery for adults. *Eur Spine J* 2013;22:402–10.

28. Schwab FJ, Hawkinson N, Lafage V, et al. Risk factors for major peri-operative complications in adult spinal deformity surgery: a multi-center review of 953 consecutive patients. *Eur Spine J* 2012;21:2603–10.
29. Deisseroth K, Hart RA. Symptoms of post-traumatic stress following elective lumbar spinal arthrodesis. *Spine* 2012;37:1628–33.
30. Hart R, Perry E, Hiratzka S, et al. Post-traumatic stress symptoms after elective lumbar arthrodesis are associated with reduced clinical benefit. *Spine* 2013;38:1508–15.
31. Boden SD, Davis DO, Dina TS, et al. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects. A prospective investigation. *J Bone Joint Surg Am* 1990;72:403–8.