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Validity, Reliability, and Responsiveness of SRS-7 as an Outcomes Assessment Instrument for Operatively Treated Patients With Adult Spinal Deformity

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Study Design. A retrospective analysis.

Objective. The aim of our study was to compare the normality, concurrent validity, internal consistency, responsiveness, and dimensionality of an item response theory–derived seven-question instrument (SRS-7), against the Scoliosis Research Society-22r (SRS-22r) questionnaire in operatively treated patients with adult spinal deformity (ASD).

Summary of Background Data. Compared with SRS-22r, SRS-7 (which has been validated in operatively treated patients with adolescent idiopathic scoliosis) has advantages of being short, unidimensional, and linear.

Methods. A prospective database of ASD patients was queried for patients 18 years or older who were operatively treated, and who answered pre- and postoperative (at 2-year follow-up) SRS-22r questions ($n = 276$). Corresponding SRS-7 scores were calculated using answers to SRS-22r items 1, 4, 6, 10, 18, 19, and 20. Significance was set at a P value less than 0.01.

Results. SRS-7 and SRS-22r were normally distributed preoperatively but not postoperatively. SRS-7 and SRS-22r scores had high correlation both preoperatively ($r = 0.76$, $P < 0.01$) and postoperatively ($r = 0.83$, $P < 0.01$). The internal consistency reliability Cronbach α values were 0.61 (SRS-7) and 0.83 (SRS-22r) preoperatively and 0.91 (SRS-7) and 0.95 (SRS-22r) postoperatively. SRS-7 was found to be more responsive than SRS-22r with measures of effect size: Cohen $d = 1.21$ *versus* 1.13, Hedge $g = 1.21$ *versus* 1.13, and effect size correlation $r = 0.52$ *versus* 0.49. Iterative principal factor analysis of pre- and postoperative scores showed the presence of one dominant latent factor in SRS-7 (unidimensionality) and four latent factors in SRS-22r (multidimensionality).

Conclusion. SRS-7 is a valid, reliable, responsive, and unidimensional instrument, which can be used as a short-form alternative to the SRS-22r for assessing global changes in patient-reported outcomes over time in patients with ASD.

Key words: adult spinal deformity, patient-reported outcomes, Scoliosis Research Society questionnaire.

Level of Evidence: 3

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The Scoliosis Research Society (SRS) questionnaire is a disease-specific instrument that was initially developed for the assessment of children with adolescent idiopathic scoliosis (AIS).[1,2] The SRS questionnaire went through a few iterations, consisting of the SRS-24, the

SRS-22, and the latest SRS-22r version.[3,4] The SRS-22r consists of 22 questions covering five domains and has been widely used for evaluation of health-related quality of life (HRQOL) in patients with adult spinal deformity (ASD).[5–12]

The SRS questionnaire was designed on principles of classical test theory,[13] which stipulate that the observed score on a test is a combination of the true score and some error. The main shortcomings of this approach are that it does not distinguish between the characteristics of the test and the test-taker, account for the difficulty of a given item, or account for the ability of the test-taker. Therefore, if two examinees incorrectly answer one question each, they would be assumed to have the same knowledge, without considering the difficulty of the questions they missed or their own intrinsic abilities. The results obtained from Likert-type questionnaires based on classical test theory are ordinal data, which can be used for rank-ordering.[14] Use of traditional parametric statistics, such as *t* tests, on SRS-22r data is statistically inappropriate in the strictest sense because the data are not interval in nature.

An alternative framework for questionnaire development, item response theory, specifies that an assessment should have interval linearity (*i.e.*, a one-point change in a response to one item should equal a one-point change in a response to another item, across the spectrum of scores) and unidimensionality (measuring only one underlying trait).[15] In a 2012 study, a Swiss group analyzed the SRS-24 and found that it was nonlinear and multidimensional and yielded noninterval results.[16] In 2014, Caronni *et al.*[17] proposed the SRS-7, which is a seven-item, short-form questionnaire that meets the assumptions of a Rasch model (a special case of item response theory) and shows unidimensionality and linearity. In 2015, Jain *et al.*[18] showed that SRS-7 was a valid and responsive functional outcome measure for patients with AIS.

To our knowledge, SRS-7 has not been validated in patients with ASD. The aim of our study was to compare SRS-7 with SRS-22r in patients treated operatively for ASD. The psychometric parameters analyzed were normality, concurrent validity, internal consistency, responsiveness, and dimensionality.

MATERIALS AND METHODS

Institutional review board approval was obtained at each of the participating institutions.

Data Source and Characteristics

A prospective, multicenter registry of ASD patients was queried to identify patients who were 18 years or older and were treated operatively ($n = 564$). ASD was defined as scoliosis Cobb angle $\geq 20^\circ$, sagittal vertical alignment ≥ 5 cm, pelvic tilt $\geq 25^\circ$, and/or thoracic kyphosis $\geq 60^\circ$. Patients with neuromuscular causes or presence of active infection or malignancy were excluded. Of the 564 operatively treated ASD patients, those who answered pre- and postoperative (at 2-year follow-up) SRS-22r questions ($n = 276$) were selected. Patient and surgical characteristics are provided in Table 1.

SRS-7 Calculation

The SRS-7 was not prospectively administered at the time of the design of our multicenter registry. The SRS-7 questions are all derived from the existing SRS-22r questions (*i.e.*, they are extracted from the longer questionnaire, and in some cases, multiple response choices are combined into one choice). For the purpose of our study, SRS-7 scores were retrospectively calculated from responses to the corresponding SRS-22r questions, as previously described by Caronni *et al.*[17]

SRS-22r responses to item 1 (pain domain); items 4, 6, 10, and 19 (self-image domain); item 18 (function domain); and item 20 (mental health domain) were rescaled to SRS-7 responses using the algorithm described in Table 2. Caronni *et al.*[17] found that to reduce the effect of disordered thresholds and to improve fit to the Rasch model, some responses could be combined (*e.g.*, "very strongly" and "strongly" could be combined into "strongly"). As a result, the SRS-7 may contain fewer possible responses for an item than the corresponding item in the SRS-22r. Finally, the raw SRS-7 total scores were scaled to a 100-point linear scale as proposed by Caronni *et al.*[17]

Statistical Methods

Stata, version 12.0, software (StataCorp LP, College Station, TX) was used for all analyses. Significance was set at a *P* value less than 0.01.

To assess for normality of distributions, the Shapiro-Francia test was used[19]; a significant *P* value denotes a

TABLE 1. Characteristics and Radiographic Measurements of 276 Patients With Adult Spinal Deformity*

Characteristic	Mean ± SD
Age (yr)	55.9 ± 15.1
Female sex	83.9*
ASA Functional Classification score†	2.3 ± 0.7
Number of levels fused	11.1 ± 4.6
Length of hospital stay (d)	7.9 ± 4.6
Deformity characteristics	
Preoperative	
Thoracic kyphosis (°)	23.5 ± 35.0
Lumbar lordosis (°)	−16.2 ± 34.0
C7 sagittal vertical axis (cm)	6.1 ± 7.5
Two-year follow-up	
Thoracic kyphosis (°)	22.2 ± 16.5
Lumbar lordosis (°)	16.3 ± 12.2
C7 sagittal vertical axis (cm)	3.2 ± 5.8

ASA indicates American Society of Anesthesiologists.

**Data presented as percent.*

†According to the ASA Functional Classification, 11% of patients were grade I, 51.9% were grade II, 36.3% were grade III, and 0.8% were grade IV.

TABLE 2. Rescaling* of Responses from SRS-22r to SRS-7

SRS-22r Item No.	Question	SRS-22r Response Scheme	Rescaled Responses for SRS-7
1	Which one of the following best describes the amount of pain you have experienced during the past 6 months?	12345	12234
4	If you had to spend the rest of your life with your back as it is right now, how would you feel about it?	12345	12234
6	How do you look in clothes?	12345	12344
10	Which of the following best describes the appearance of your trunk; defined as the human body except for the head and extremities?	12345	12345
18	Does your back condition limit your going out with friends/family?	12345	11223
19	Do you feel attractive with your current back condition?	12345	12234
20	Have you been a happy person during the past 6 months?	12.345	12234

SRS indicates Scoliosis Research Society.

**The SRS-7 has fewer possibilities for response choices per item than the SRS-22r. For example, for item 1: in the SRS-22r, there are five possible response choices, whereas in the SRS-7, there are only four possible response choices. The response choices 2 and 3 in the SRS-22r are combined into choice 2 in the SRS-7.*

non-normal distribution. Concurrent validity was assessed through Pearson correlation between SRS-7 and SRS-22r scores before surgery and at 2-year follow-up.

Internal consistency reliability was assessed through Cronbach α. Cronbach α statistics were calculated for pre- and postoperative SRS-22r and SRS-7 scores. According to convention, Cronbach α more than 0.6 is considered "acceptable," more than 0.7 is "good," and more than 0.9 is "excellent."[20]

Responsiveness was assessed using pairwise Student *t* test comparisons between pre- and postoperative scores in the SRS-22r and SRS-7. Standard estimates of effect size were made using Cohen *d*, Hedge *g*, and effect size correlation coefficient *r*. In general, an instrument with a larger effect size measure is deemed more responsive.[21]

Iterative principal factor analysis was used to analyze the dimensionality of the items in the SRS-22r and SRS-7, as previously reported.[18] Factor analysis aims to ascertain the number of latent variables that explain most of the variance in a given dataset.[22] The Guttman-Kaiser criterion, which states that factors with eigenvalues greater than 1 are to be considered major, was used to identify latent factors.[22]

RESULTS

Mean and Normality

Before surgery, the mean scores were 63 points (SD = 15; range, 24–95) for the SRS-22r and 30 points (SD = 12; range, 0–61) for the SRS-7. The Shapiro-Francia test for normality showed that preoperative SRS-22r ($P = 0.08$) and SRS-7 ($P = 0.06$) scores were normally distributed (Figure 1A, B).

At 2-year follow-up, the mean scores were 82 points (SD = 18; range, 36–110) for the SRS-22r and 49 points (SD = 20; range, 0–100) for the SRS-7. The Shapiro-Francia test for normality showed that the postoperative SRS-22r and SRS-7 scores were not normally distributed (both $P < 0.01$) (Figure 2A, B).

Concurrent Validity

The correlations between SRS-22r and SRS-7 scores were 0.76 preoperatively and 0.83 postoperatively (both $P < 0.01$) (Figure 3A, B).

Internal Consistency

The preoperative internal consistency reliability Cronbach α was 0.91 for SRS-22r scores and 0.61 for SRS-7 scores. Postoperatively, these values were 0.95 and 0.83, respectively.

Responsiveness

SRS-22r and SRS-7 scores improved by 19 points each from pre- to postoperative measurements (both $P < 0.01$). Effect

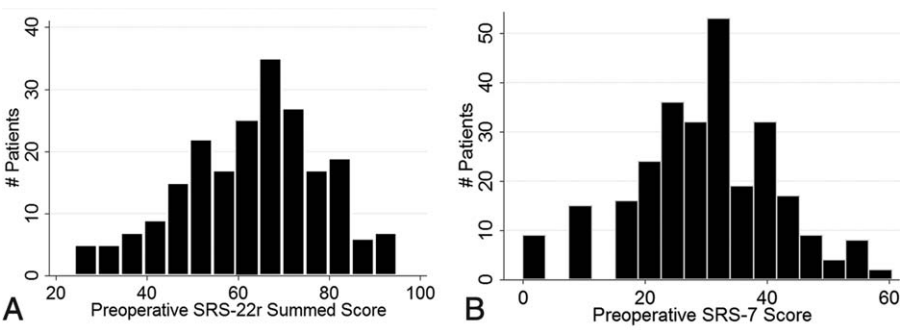

Figure 1. Frequency distributions of preoperative (**A**) SRS-22r and (**B**) SRS-7 scores of 276 patients with adult spinal deformity.

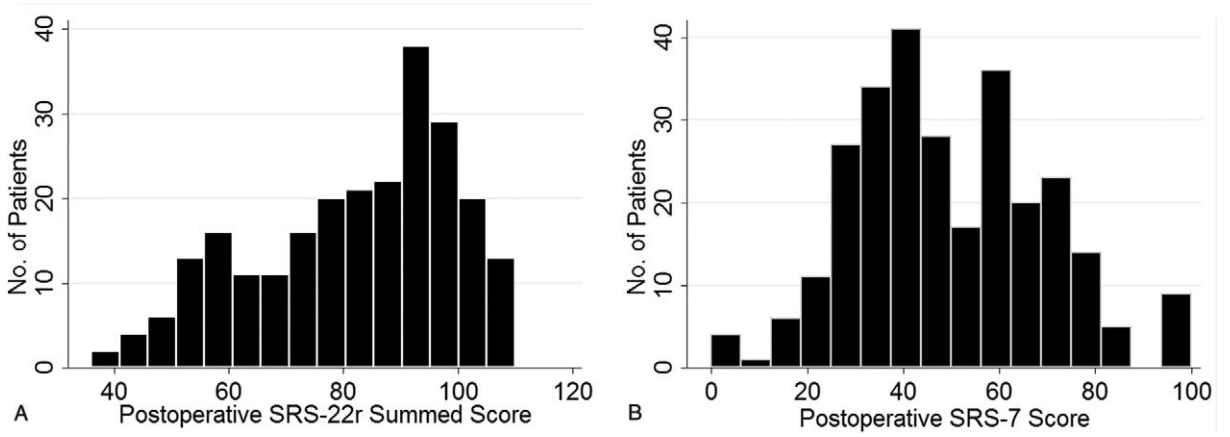

Figure 2. Frequency distribution of postoperative (2-year follow-up) (**A**) SRS-22r and (**B**) SRS-7 scores of 276 patients with adult spinal deformity.

size showed that the SRS-7 was more responsive than the SRS-22r to change after surgery in patient-reported outcomes. For SRS-22r, the effect size was Cohen $d = 1.13$, Hedge $g = 1.13$, and effect size correlation $r = 0.49$. For SRS-7, the effect size was Cohen $d = 1.21$, Hedge $g = 1.21$, and effect size correlation $r = 0.52$.

Unidimensionality

Iterative principal factor analysis of SRS-22r scores showed the presence of four latent factors with eigenvalues greater than 1 before surgery and at 2-year follow-up, suggesting that the SRS-22r is a multidimensional construct. In contrast, the iterative principal factor analysis of SRS-7 scores showed the presence of one latent factor with eigenvalues greater than 1 before surgery and at 2-year follow-up, suggesting that the SRS-7 is a unidimensional instrument.

DISCUSSION

The modern SRS-22r questionnaire originated from the SRS Outcomes Instrument, which consisted of 55 items covering seven domains, some of which were adapted from components of the 36-Item Short Form Health Survey.[2] Other items were designed to specifically assess the association of spinal deformity with HRQOL in children with AIS.[2,23] The next iteration of the questionnaire, the SRS-24, attempted to eliminate domains with similar content and was condensed to 24 questions spanning five domains.[24] Each item was designed to have a Likert-type 5-choice response, and the mean summed score was used for analysis. Since the introduction of the SRS questionnaire, the mean scores by domain and overall have been frequently used for outcomes assessment in patients with AIS or ASD.[7,25–29]

Despite its widespread use for HRQOL assessment in patients with AIS or ASD, the original SRS questionnaire and its modifications (including the SRS-24 and the SRS-22r) do not satisfy the item response theory criteria of linearity and unidimensionality. The difficulty of the questions and the ability of the test-taker are not taken into account. The results obtained from these instruments are ordinal and not linearly distributed on an interval scale. For example, a one-point difference in the overall score that results from changing an answer in the self-image domain may not produce the same quality-of-life difference as a one-point difference in the overall score that results from changing an answer in the mental health domain. Although frequently performed, analysis of ordinal data obtained from SRS questionnaires *via* traditional arithmetic operations and parametric statistics, such as mean and *t* tests, is inappropriate. Nonetheless, ordinal data can be used readily for rank-ordering.[14]

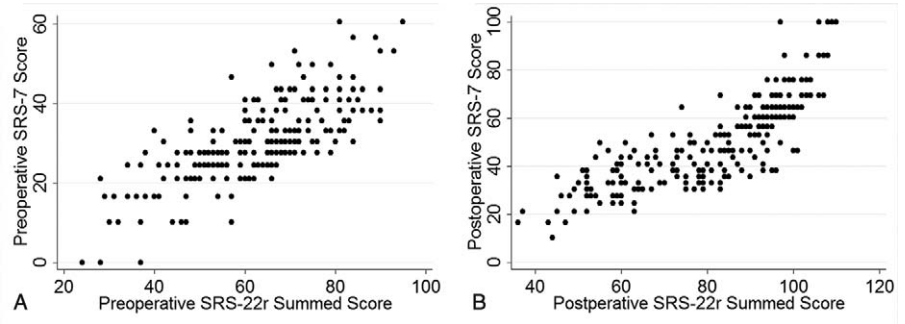

Figure 3. Correlation of (**A**) preoperative and (**B**) postoperative SRS-22r and SRS-7 summed scores of 276 patients with adult spinal deformity.

To our knowledge, there are no disease-specific HRQOL measures for patients with ASD described in the literature that meet the validity assumptions of item response theory. Jain *et al.*[18] showed that in patients with AIS, the SRS-7 possessed desirable psychometric properties such as concurrent validity and responsiveness, while being linear and unidimensional. In the current study, we found that SRS-7 scores correlated well with SRS-22r scores before surgery and at 2-year follow-up. Further, the SRS-7 was slightly better than the SRS-22r in terms of responsiveness in all effect size measures. Greater responsiveness implies that the instrument possesses greater sensitivity to HRQOL change after surgical intervention.

The ''gold standard'' for assessment of an instrument's reliability is performing a test-retest comparison of the scores. In our study, we did not collect retest data. We used internal consistency as a measure of reliability, as estimated *via* Cronbach α. However, one of the major drawbacks of this approach is that Cronbach α is influenced by the number of items in a questionnaire, and the value increases for a longer questionnaire.[20,30] We found that the Cronbach α was greater for the SRS-22r (the longer instrument) than for the SRS-7 (the shorter instrument). Nevertheless, the pre- and postoperative internal consistency of the SRS-7 were within the ''acceptable'' and ''good'' categories, respectively.

In addition to its excellent responsiveness and ''acceptable'' to ''good'' internal consistency reliability, a strength of the SRS-7 is its unidimensionality, with one underlying latent trait being measured. This is a potential advantage of the SRS-7 compared with the SRS-22r, which measures multiple latent traits. A unidimensional instrument may be more appropriate when assessing global changes in patient outcomes over time (*e.g.,* comparing outcomes before and at various time points after surgery). In theory, the underlying dimension the SRS-7 instrument measures is ASD. However, because ASD is associated with several problems, including cosmesis, pain, and function, a multidimensional instrument is likely better for assessing HRQOL changes associated with individual aspects of the disease.

A major weakness of our study is that SRS-7 values were derived retrospectively using SRS-22r data. Although we expect that patients may prefer a seven-item questionnaire over a 22-item questionnaire, the SRS-7 was not administered prospectively in a clinical setting in our study. Further, conversion of SRS-22r responses to SRS-7 responses (in which some items have fewer choices) may have introduced an element of error because patients might have chosen a different response if presented with fewer choices. We aim to include the SRS-7 in our future clinical studies for patients with spinal deformity. Another potential weakness of our study is that only 49% of patients had complete SRS-22r data at baseline and at the 2-year follow-up. Hypothetically, we may have lost to follow-up a portion of patients who had poor results, which would have made the standard deviations around the patient-reported outcome scores artificially smaller, and thus influenced the effect size calculations. A prospective study with greater follow-up could help construct better estimates of the effect sizes associated with SRS-22r and SRS-7.

Another area of future study would be a comparison of the item response theory–based Patient-Reported Outcomes Measurement Information System questionnaires developed by the National Institutes of Health (Bethesda, MD) *versus* the traditional classical test theory–based 36-Item Short Form Survey and SRS-22r.

CONCLUSION

The SRS-7 is a valid, reliable, responsive, and unidimensional instrument that may be used as an alternative to the SRS-22r for assessing global changes in patient-reported outcomes over time in patients with ASD. However, the SRS-7 needs to be further evaluated in large, prospective studies in patients with ASD.

➢ Key Points

- ❑ SRS-7 is an item response theory–derived 7-question spinal deformity–specific outcomes instrument that has been previously validated in patients with adolescent idiopathic scoliosis.
- ❑ In patients with ASD, we find that SRS-7 is valid, reliable, responsive, and unidimensional.
- ❑ SRS-7 can be used as a short-form alternative to the SRS-22r for global assessment of functional outcomes in patients with ASD.

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