Physical Functioning in Adolescents with Idiopathic Scoliosis

A Systematic Review of Outcome Measures and Their Measurement Properties

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Study Design. A systematic review.

Objective. To summarize evidence on measurement properties of Outcome Measures (OM) used to assess physical functioning in adolescents with idiopathic scoliosis (AIS).

Summary of Background Data. The AIS is a common spine deformity in those aged 10 to 18 years old. Associated health problems (e.g., back pain) significantly impact the quality of life (QoL). One important domain in QoL is physical functioning, which can be measured with patient-reported outcome measures (PROM), performance-based outcome measures (PBOM), and body structure and function OM. Adequate measurement properties of OM are important for precision in research and practice.

Methods. A two-staged search strategy was performed on electronic databases up to December 2019. Search one revealed a list of OM was used for physical functioning assessment in AIS. Search two identified studies that evaluated the measurement properties of OM in AIS; using the list identified in search one. Two independent reviewers determined study eligibility, risk of bias assessment (CONsensus-based Standards for the selection of health Measurement INstruments [COSMIN] checklist), and performed data extraction. The level of evidence was established using a modified GRADE approach.

Results. Search one yielded: 28 PROM, 20 PBOM, and 10 body structure and function OM. Search two revealed: 16 measurement properties studies for PROM, one for PBOM, and three for body structure and function measures. Construct validity, reliability, and responsiveness of most PROM has been established in AIS, but not content validity or internal consistency (moderate evidence). Construct validity was sufficient for the Timed Up and Go test and body structure and function measures (very low to low evidence).

Conclusion. Currently, physical functioning is evaluated with a variety of measures in AIS. The majority of measurement properties studies evaluated PROM with a paucity of information on measurement properties of PBOM and body structure and function OM. Based on COSMIN methodology, none of the OM identified in this review can be recommended with confidence in individuals with AIS.

Key words: idiopathic scoliosis, measurement properties, outcome assessment, physical functioning, reliability, systematic review, validity.

Level of Evidence: 2

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Adolescent idiopathic scoliosis (AIS) is the most common spine deformity among children aged 10 to 18 years old, with prevalence ranging 1% to 3%. Comprising of a lateral curvature and axial rotation of spinal vertebrae, the cause is unknown in most cases. AIS has been linked to back pain, psychological stress, and respiratory dysfunction, potentially impacting on quality of life (QoL).

A dimension of any QoL measurement is “physical functioning,” this being the ability to carry out activities of daily living. Physical functioning limitations have been associated with an increased risk of disability and predictive of social and healthcare use. Limitations include walking and maintaining body positions, as well as pain related functional restriction. Corrective surgery is used for some, necessitating a long recovery period and often associated with pain and immobility in adolescence. Measuring the impact of AIS is therefore important in both research and clinical practice.
Physical functioning can be evaluated with patient-reported outcome measures (PROM), performance-based outcome measures (PBOM), and measures of body structure and function. Each measure assesses different, but complementary, aspects of physical functioning, with PROM for self-report, PBOM for the performance of a specific activity (e.g., chair stand test), and body structure and function providing anatomical data (e.g., range of motion) or a physiological process (e.g., muscle strength).

Outcome measures need adequate measurement properties to assure truthfulness of results and avoid risk of bias. The COmmittee on the Standardization of Measurement Instruments (COSMIN) group developed a taxonomy of measurement properties to enable this. Three main domains are validity, reliability, and responsiveness. The COSMIN group provide guidelines for conducting a systematic review for PROM, which can be adapted for other OM.

The Scoliosis Research Society questionnaire (SRS-22) and its' variants are the most widely used PROM in this population. From the core outcome study (COS), SRS-22 revised (SRS-22r) is recommended and the considered reference standard for evaluating physical functioning for adolescents and young adults with spine deformity. However, SRS-22r does not capture all aspects of physical functioning, such as mobility and self-care. Furthermore, the COS study included all forms of spinal deformities; the heterogeneity limiting applicability to individuals with AIS. Furthermore, little is known about PBOM and body structure and function measures for individuals with AIS.

In the absence of existing relevant reviews, the purpose of this review was to identify OM used to assess physical functioning in individuals with AIS, and secondly to evaluate their measurement properties.

METHODS

Design
This review was conducted according to a registered (PROSPERO CRD42019142335) and published protocol. Designed in line with COSMIN methodology for systematic review of PROM, the review is reported in line with Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement.

Search Strategy
The search was conducted in two parts. Search one identified and generated a list of OM used for assessment of physical functioning in AIS. Search two identified the studies of measurement properties using the list from search one. Details of both search are listed in Table 1.

Data Sources
A comprehensive search was performed using MEDLINE, PsycINFO, EMBASE, CINAHL, SPORTdiscus, Web of Science, and PubMed databases from date of inception until December 2019. As well as searches on key journals, reference lists, conference proceedings, and grey literature were also searched. The search terms were first developed for MEDLINE and then adapted with relevant syntax and subject headings for the other databases. Supplemental digital content 1, http://links.lww.com/BRS/B720 shows example of search one and two.

| TABLE 1. Search One and Search Two Strategy |
|---------------------------------------------|
| **Search One (Inventory of Outcome Measure)** | **Search Two (Measurement Properties)** |
| Inclusion criteria | Individuals with AIS ($\geq 10^\circ$ Cobb angle)$^1$ Age 10–18 years old |
| | Individuals with AIS ($\geq 10^\circ$ Cobb angle)$^1$ Age 10–18 years old Mixed cohort studies $>50\%$ of participants with AIS |
| | Any study design that included assessment of physical functioning for individuals with AIS. No limitations were applied on type of outcome measure, language or location. |
| | Measurement properties studies (i.e., content validity, structural validity, construct validity, reliability, and responsiveness) of outcome measure identified in search one. |
| Outcome measure defined as following: | PROM in form of questionnaires, scales or sub-scales, designed to evaluate physical functioning in AIS. PBOM, meaning a clinician-observer measure of an “activity” such as the execution of a task or action by an individual, measured by/or time, or distance. Body structure and function measures defined as “the physiological function of body systems and/or the anatomical parts of body.”$^{12,15}$ |
| Exclusion criteria | Radiographs, laboratory-based measures, anthropometric measures.$^{26–32}$ Studies in non-English speaking population Systematic reviews Studies providing normative data Studies providing indirect evidence on measurement properties. |

AIS indicates adolescent idiopathic scoliosis; PBOM, performance-based outcome measure; PROM, patient reported outcome measure.
Study Selection
Two independent reviewers (S.A., E.B.) assessed studies based on the title and abstract for eligibility. In case of insufficient information, full text articles were retrieved and screened for eligibility. The reviewers discussed findings and reached consensus on eligibility of studies. The percentage agreement between reviewers was estimated using the κ statistic (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp).

Data Extraction
Two reviewers (S.A., E.B.) independently extracted data of eligible studies. Information about study, participants characteristics, outcome measures, and measurement properties were extracted. If information was not clear or unavailable in studies, corresponding authors were contacted.

Risk of Bias Assessment
The risk of bias for each measurement properties was assessed using COSMIN checklist. Adoptions were made for studies of body structure and function, for example, interobserver reliability. This involved removal of inapplicable standards, that is, “was the time interval appropriate?” Each item of measurement property was rated as either “very good,” “adequate,” “doubtful,” or “inadequate quality.” Subsequently overall methodological quality of measurement property was rated based on “the worst score counts principle.” Two independent reviewers (S.A., E.B.) assessed study quality and inconsistencies were resolved by discussion.

Hypotheses for Construct Validity and Responsiveness
Hypotheses for evaluating construct validity and responsiveness assessed in included studies, were pre-defined and listed in supplemental digital content 2, http://links.lww.com/BRS/B721.

Data Analysis and Synthesis
The necessary homogeneity in studies results was insufficient, thus meta-analysis was not performed. Results were therefore synthesized and qualitatively summarized. The measurement property for each study was rated according to updated criteria for good measurement properties as sufficient (+), insufficient (−), or indeterminate (?). Then, evidence was graded using modified Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach. Five factors determine quality of evidence: risk of bias, inconsistency, indirectness, imprecision, and publication bias. For evaluating measurement properties in systematic reviews of PROM, only four factors were assessed, with fifth factor (publication bias) removed.

RESULTS
The PRISMA flow diagram shows results of both searches, selection process, and reasons for exclusion (Figure 1).

Search One: Inventory of Outcome Measure
A list of OM was generated and classified into 28 PROM, 20 PBOM, and 10 body structure and function OM are listed in supplemental digital content 3, http://links.lww.com/BRS/B722. The International Classification of Functioning, Disability and Health (ICF) model was used to classify OM into either PBOM or body structure and function OM. Agreement between reviewers (S.A., E.B.) for title and abstract assessment was excellent (94.0%, Kappa = 0.91) and full-text (92.5%, Kappa = 0.80). The third reviewer (N.R.H.) was consulted twice.

Search Two: Measurement Properties
There were 16 studies for measurement properties of PROM, one study for PBOM, and three studies for body structure and function OM (Table 2). Excellent agreement between reviewers (S.A., E.B.) for titles/abstracts (95%, Kappa = 0.92) and substantial agreement for full-text articles (90%, Kappa = 0.78). Eleven authors responded from 21 who were contacted clarifying participants age, language of PROM utilized, or for missing data. The third reviewer (N.R.H.) was consulted four times.

Study and Outcome Measure Characteristics
Detailed information on studies and participant characteristics are shown in Table 2. The OM included were nine PROMs (six disease-specific and three generic), one PBOM, and six body structure and function OM. Detailed description of OMs and their characteristics are shown in Tables 3 and 4.

Risk of Bias
Evaluated measurement properties included, development (n = 1), internal consistency (n = 3), reliability (n = 5), measurement invariance (n = 2), measurement error (n = 2), hypothesis testing for construct validity (n = 18), responsiveness (n = 2). Results of risk bias assessment are presented in supplemental digital content 4, http://links.lww.com/BRS/B723.

Measurement Properties and Synthesis of Evidence
Table 5 shows the summary of findings table for results of measurement properties and the overall evidence for measurement properties against COSMIN and GRADE approach.

Patient-Reported Outcome Measures
Functional scales of SRS-24 displayed sufficient discriminative validity in pre and postsurgery individuals with AIS. While, construct validity of SRS-22 function scale was rated insufficient (moderate-quality evidence), and sufficiently responsive (very low-quality evidence). Measurement invariance of this scale was rated indeterminate since no multiple group factor analysis was performed, and the measurement error rated insufficient. The activity scale of SRS-22r was rated sufficiently reliable as the Interclass Correlation Coefficient (ICC) was 0.76 (0.56– 0.80)
supported by low-quality evidence. However, internal consistency was rated indeterminate. The SRS-22r showed insufficient measurement error (moderate-quality evidence). A strong correlation between function scale of SRS-22r with mobility scale of Child Health Questionnaire-Child Self-Report Form 87 (CHQ-CF87) (Pearson $r = 0.73$) indicating sufficient convergent validity. While, hypothesis of discriminative validity was not met. Thus,
| Reference          | Name of OM | Country | Age (Mean ± SD) Range | Gender (n) | Sample Size (n) | Curve Type (%) (n) | Curve Size Degree ± SD (n) | Type of Intervention (n) | Score (Mean ± SD) |
|--------------------|------------|---------|-----------------------|------------|----------------|--------------------|---------------------------|------------------------|-----------------|
| Feise et al<sup>8</sup> | SQLI       | Canada  | 14.9 ± 2.4 (10–18)    | F (70) M (14) | 84             | NR                 | Unbraced 26.1 ± 10°       | Postsurgical (16) Braced (30) Unbraced (24) Control (14) | 81.1 ± 15.7     |
| Parent et al<sup>8</sup> | SQLI       | Canada  | 14.7 ± 1.9 (6–20)     | F (95)      | 95             | Main thoracic (2.9); Double thoracic (4); Double major (2); Thoracolumbar/lumbar (20); Thoracolumbar/lumbar, main thoracic (17) | Postsurgical (16) Braced (30) Unbraced (24) Control (14) | NR             |
| Bastions et al<sup>30</sup> | SRS-24, SRS-22 | USA   | 14.8 ± 2 (10–21)      | F (81%)     | 829            | Lenke 1 (43%); Lenke 2 (20%); Lenke 3 (7%); Lenke 4 (4%); Lenke 5 (16%); Lenke 6 (10%) | Presurgery 55° ± 13° Post surgery 20° ± 9° | Pre- and Postsurgery | NR             |
| Asher et al<sup>37</sup> | SRS-22     | USA     | 16.4 (10.6–47.3)      | F (48) M (10) | 58             | Single (36%); Double (19%); Triple (5) | 63° | Surgery | Function (0 mo) 4.1 Function (3 mo) 3.3 Function (6 mo) 3.9 Function (12 mo) 4.2 Function (24 mo) 4.1 |
| Asher et al<sup>37</sup> | SRS-22     | USA     | Control 13 (10.7–15.4); Non-surgical untreated 14 (10.6–16) Non-surgical treated 14 (9.9–15.2); Presurgery 14 (10.6–15.6) | Control F (15) M (4); Non-surgical F (57) M (11); Non-surgical treated F (44) M (10); Non-surgical treated F (31) M (1); Presurgery F (31) M (1) | Total (119) | Control (19); Non-surgical (68 Unbraced (54) Braced (14); Presurgery (32) | Thoracic, thoracolumbar, lumbar, double triple; Largest Cobb angle; Non-surgical untreated 2°; Braced 31° Presurgery 61° | Brace, presurgery, control | Control (4.5 ± 0.5) Non-surgical (4.4 ± 0.36) Non-surgical untreated (4.4 ± 0.37) Non-surgical braced (4.5 ± 0.32) Presurgery (4.2 ± 0.42) |
| Parent et al<sup>8</sup> | SRS-22     | Canada  | 13.5 ± 20 (153); Total (18.6 ± 9.2) | F (153)     | 153            | NR                 | 30° (5.6); 30°–50° (66) 50° (4) | Observation (107) Bracing (32) Presurgery (23) Postsurgery (62) | Observation (4.3 ± 0.59) Bracing (4.5 ± 0.59) Presurgery (4.2 ± 0.35) Postsurgery (4.1 ± 0.60) |
| Campeon et al<sup>82</sup> | SRS-22     | USA     | 14.3 ± 1.9 (10–18)    | F (735) M (152) | 887           | NR                 | 53° ± 18° | Pre and 1 year postsurgery | Presurgery 4.15 ± 0.55 Postsurgery 4.3 ± 0.46 |
| Verma et al<sup>85</sup> | SRS-22     | USA and Ghana | 13.4                     | F (100) M (60) | 160           | NR                 | 67° 2° USA 52° | Presurgery | Ghana 3.7 ± 0.8 USA 4.2 ± 0.4 |
| Berliner et al<sup>88</sup> | SRS-22 r    | USA     | 13.8 (11.0–17.2)      | F (115) M (40) | 155            | Non-surgical thoracic (56.5%); Thoracolumbar (18.7%); Lumbar (48.4%); Presurgical thoracic (65.2%); Thoracolumbar (43.8%); Lumbar (20%) | 43.1 Non-surgical 21.9° Presurgical 5.7° | Non-surgical and presurgical 0°–19° (4.5 ± 0.47) 20°–40° (4.4 ± 0.37) 41°–50° (4.1 ± 0.60) 51°–60° (4.2 ± 0.54) >60° (4.3 ± 0.55) |

**TABLE 2.** Studies and Participants Characteristics

**Spine**

**LITERATURE REVIEW**

Adolescent Idiopathic Scoliosis Outcome Measures • Alamrani et al
| Reference       | Name of OM | Country | Age (Mean ± SD) Range | Gender (n) | Sample Size (n) | Curve Type (%) (n) | Curve Size Degree ± SD (n) | Type of Intervention (n) | Score (Mean ± SD) |
|-----------------|------------|---------|-----------------------|------------|-----------------|--------------------|------------------------|-------------------------|-----------------|
| Kelly et al     | SRS-22r    | USA     | 14.6 (10–22)          | F (1,034)  M (247) | 1,281           | Lenke 1 (52%) Lenke 2 (27.2) Lenke 3 (93) Lenke 4 (46) Lenke 5 (196) Lenke 6 (120) | NR                     | 1, 2 year Postsurgery | Activity MCID (0.08) MDMD (0.24) |
| Glattes et al   | SRS-22r, CHQ-CF87 | USA     | 14.1 ± 2.7 (6–16)     | F (58) M (12) | Total (70)     | NR                 | 29.8 ± 12.3             | Presurgery            | SRS-22r (4.5 ± 0.65) CHQ-CF87 (91 ± 35.6) |
| Fedorak et al   | PROMIS, SRS22r | USA     | 14.4 ± 2.1 (11.4–17.4) | F (78.8%) M (21.2%) | 113            | Thoracic (67%) Thoracic lumbar (21.7%) Lumbar (11.3%) | Thoricic kyphosis 3.4 ± 1.9 Lumbar lordosis 54.6 ± 13.3 | Observed, Pre or postsurgery (69.0%) Braces (27.4%) Surgery (3.5%) | PROMIS, Mobility (50.9 ± 9.8) SRS-22r, Function (4.5 ± 0.5) |
| Roberts et al   | SRS-30     | USA     | 14.0 (15.2)           | F (83.4%) M (16.5%) | 744            | Risser grade M (mean 3.5) F (mean 3.2) | F (53.3%) M (55.9%) | Presurgery, 2 yr. Postsurgery | Presurgery F (4.2) M (4.4) Postsurgery F (4.3) M (4.4) |
| Lubicki et al   | SRS-30     | USA     | 15.6 ± 1.7            | F (75%)     | 356            | NR                 | NR                     | Presurgery, 2 yr. Postsurgery | Presurgery F (4.18 ± 0.55) Postsurgery (4.34 ± 0.51) |
| Sarwahi et al   | SAQ        | USA     | 15 (13 to 17)         | F (71) M (24) | 95             | NR                 | NR                     | NR                     | NR              |
| Lerman et al    | PODCI      | North America | Patient 15.2 (11.7–18.8) | Patient 15.3 (11.7–20.9) | 102            | Thoracic (17) Thoracic lumbar (6) Lumbar (7) Double curve (17) | 10–29 (n = 23) 20–49 (n = 20) >50° (n = 4) | 1 year postsurgery | Upper extremity (96.8 ± 9.9) Transfer (97.6 ± 4.7) Sport & physical function (85.5 ± 17.5) Global function (89.4 ± 9.8) |

**Performance-based outcome measure:**

| Gao et al       | TUG        | USA     | Mild AIS: 14.9 ± 1.7 Moderate AIS: 16.4 ± 3.3 Severe AIS: 15.3 ± 3.1 | NR | AIS (30) Control (30) | Right-sided Thoracic lumbar: Mild AIS 19.9 ± 4.3 Moderate AIS 31.8 ± 4.2 Severe AIS 53.4 ± 16.1 | Thoricic rotation 1.1 ± 12.1 | Treatment | TUG (seconds) | Mild (6.8 ± 1.5) Moderate (6.9 ± 0.9) Severe (6.5 ± 0.8) Healthy control (6.0 ± 0.6) |

**Body structure and function outcome measure:**

| Hresko et al    | MST        | USA     | 14.2 ± 1.9 (11.3–18.6) | F (37) | 37            | Thoracic Lumbar | Thoracic 40° ± 20° Lumbar 31° ± 12° | Treatment | 5.7 ± 2.2 cm |
| Eyvazov et al   | MST, FFI test, Axial rotation, LSB, ΔC7-PSIS | China | 15.7 ± 4.1 M (12) F (46) | 58 | Lenke 5 (Thoracic lumbar/lumbar) Group A: 25° ± 7.1 Group B: 49.8° ± 13.6 Total 34° ± 9.2 | Thoracic 27.7° ± 11.4 Lumbar 25.8° ± 10.5 |  |  |  |
| Slupienski et al | TPHA test  | Poland | AIS (12.7 ± 2.6) Control (11.8 ± 2.5) | F (98) | Control (49) AIS (49) | Risser sign Grade 0 (14) Grade 1 (11) Grade 2 (6) Grade 3 (3) Grade 4 (9) Grade 5 (6) | Thoracic 27.7° ± 11.4 Lumbar 25.8° ± 10.5 | Physiotherapy | AIS Left TPHA −10.93° ± 4.64° Right TPHA −2.37° ± 8.30° Control | AIS Left TPHA −11° ± 3.30° Right TPHA −8.64° ± 4.70 |

AIS indicates adolescent idiopathic scoliosis; C7-PSIS, cervical 7 to posterior superior iliac spine; CHQ-CF87, Child Health Questionnaire-Child Self-Report Form 87; F, Female; FFI, Fingertip To Floor test; LSB, lateral side bending; M, Male; MCID, minimal clinically important difference; MDMD, minimal detectable minimal difference; MST, Modified Schober test; NR, not reported; OM, outcome measure; PODCI, Paediatrics Outcomes Data Collection Instrument; PROMIS, patient-reported outcomes measurement information system; SAQ, sport activity questionnaire; SD, standard deviation; SQLI, scoliosis quality of life index; SRS, Scoliosis Research Society; SRS-22r, Scoliosis Research Society-22 Revised; TPHA, Trunk Pelvis Hip Angle test; TUG, Timed Up and Go test; USA, United States of America.
| PROMS     | Country      | Sub-scale Items (n)                                      | Target Population | Mode of Administration | Recall Period | Response Options | Scoring System | Available Translations |
|-----------|--------------|--------------------------------------------------------|-------------------|------------------------|---------------|------------------|-----------------|------------------------|
| SRS-24    | USA          | General Function (1)                                   | AIS               | Self-administrated     | Now, postsurgery | Five response options | 1–5            | –                      |
| SRS-22    | USA          | Function/Activity (5)                                   | AIS               | Self-administrated     | Now, postsurgery | 5 response options  | 1–5            | Turkish, Italian, Spanish, Japanese, Traditional Chinese, Simplified Chinese, Polish, French, Thai, Norwegian |
| SRS-22r   | USA          | Function/Activity (5)                                   | AIS               | Self-administrated     | Now, postsurgery | 5 response options  | 1–5            | German, Greek, Dutch, Chinese, Brazilian, Italian, Thai, Arabic, Persian, Swedish |
| SRS-30    | USA          | Function/Activity (5) post-surgery questions (2)        | AIS               | Self-administrated     | Now, postsurgery | Function/Activity (5 response options) | Postsurgery (three response options) | Function (1–5) postsurgery (1–3) | Finnish, Brazilian |
| CHQ-CF87  | USA          | Physical functioning (9)                               | Generic           | Self-administrated     | NR             | Four, five, six response options | 0–100          | –                      |
| SQLI      | Canada       | Physical activity (5)                                  | AIS               | Self-administrated     | Four weeks      | Five response options | 0–4            | –                      |
| SAQ       | USA          | Total (24) School, gym, carry backpack, bend over, running | AIS               | Self-administrated     | Postsurgery     | NR               | NR             | –                      |
| PROMIS    | USA          | Mobility                                               | Generic           | Self-administrated     | 7-day          | Five response options | Mean T-score 50, SD 10 | –                      |
| PODCI     | North America| Upper extremity functioning, Transfers & basic mobility | Generic           | Paediatric orthopaedic conditions | Self-administrated parent-report Adolescents report | NR | 3–6 | 0–100 | – |
A difference in activity scores (0.50) observed at In upright posture, knees straight, bend to The questionnaire was Performance-Based and Body Structure and Function Outcome Measure Characteristics

Very low
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Moderate-quality
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while
A very low-quality
rated indeterminate as evidence of sufficient

TABLE 4. Performance-Based and Body Structure and Function Outcome Measure Characteristics

| Outcome Measure (Reference) | Activity | Required Equipment | Number of Trials | Parameter Measured |
|-----------------------------|----------|--------------------|------------------|--------------------|
| TUG\(^{31}\)               | Stand from chair, walk 3 m, return, sit down | Chair, stopwatch, walking space | Three trials | Average of time in seconds |
| MST\(^{32,33}\)            | Marks on PSIS, keep knees straight, bend forward and touch the floor | Tape measure | Two to three trials | Average of distance in cm |
| FTF test\(^{34}\)          | Stood upright, bend forward and touch the floor | Tape measure | Two trials | Average of distance in cm |
| C7-PSIS distance\(^{34}\)  | Stand upright, maximally flex and extend neck, distance measured between C7 spinous process and PSIS | Tape measure | Two trials | Average of distance in cm |
| LSB angles\(^{31}\)        | In upright posture, knees straight, bend to the side without rotation | Goniometer | Two trials | Average angle in degrees between lines joining PSIS and C7 |
| Axial rotation\(^{34}\)    | Seated position, locked both arms in front of body with fixed pelvic, shoulder rotation controlled by a goniometer holder device | Goniometer | Two trials on left and right side | Average angle in degrees |
| TPHA\(^{54}\)             | Supine, flex and pull lower limbs, then move limbs to the left or right side | Plurimeter | Three times on each side of body | Average of angle in degrees |

C7-PSIS indicates cervical 7 to posterior superior iliac spine; FTF, Fingertip To Floor test; LSB, lateral side bending; MST, Modified Schober Test; TPHA, Trunk Pelvis Hip Angle test; TUG, Timed Up and Go test.

evidence for construct validity was downgraded for inconsistency. Moreover, the scale was found unresponsiveness to change (low-quality evidence).  

The SRS-30 consists of questions from both SRS-24 and SRS-22. Although no study was identified evaluated its validity or reliability, high-quality evidence indicated that the construct validity of activity scale of SRS-30 was sufficient.\(^{48}\) A difference in activity scores (0.50) observed at instrumentations construct before and after surgery, while measurement invariance was rated indeterminate.  

Scoliosis quality of life index (SQLI) is a modified version of SRS-22 consisting of physical activity domain.\(^{16}\) Very low evidence demonstrated that its content validity is sufficient based on reviewers’ ratings only.\(^{79}\) The questionnaire was tested for comprehensibility among healthy school children (9.9 years old) only.\(^{36}\) Per COSMIN guidance, those children may not consider as representative to population of interest.\(^{79}\) The internal consistency of activity scale was rated indeterminate, while its reliability was insufficient (ICC = 0.46, 0.29–0.63). The evidence was downgraded due to serious risk of bias and imprecision. Moderate-quality evidence showed that construct validity of this scale was sufficient.  

Mobility scale of patient-reported outcomes measurement information system (PROMIS)\(^{46}\) correlated with function scale of SRS-22r \((Pearson r = 0.65)\)^\(^{46}\) indicating sufficient construct validity, while functional domains of Paediatrics Outcomes Data Collection Instrument (PODCI) had insufficient construct validity.\(^{50}\)  

Internal consistency of physical functioning scale of \((CHQ-CF87)\)^\(^{18}\) rated indeterminate as evidence of sufficient structural validity is not available,\(^{33}\) while its reliability scale was sufficient \((ICC = 0.73, 0.20–0.85)\) based on low-quality evidence.  

The sport activity questionnaire (SAQ) was developed based on a test-retest method, which is considered a reliability study based on COSMIN definitions.\(^{15}\) A very low-quality evidence showed that reliability of SAQ was sufficient.  

In conclusion, according to COSMIN methodology for a PROM to be recommended for use, it should exhibit any level of sufficient content validity and low level of evidence of sufficient internal consistency.\(^{33}\) None of the identified PROMs in this review met these criteria, thus we are unable to recommend any of these PROMs for use in individuals with AIS. Furthermore, none of these PROM had a high evidence of insufficient measurement properties. Therefore, these PROMs can be used but it requires further assessment of the quality of its measurement properties to be recommended for use with individuals with AIS.\(^{33}\)  

**Performance-Based Outcome Measure**

Timed Up and Go test (TUG) is the only performance measure identified in this review with its measurement properties tested in AIS. A difference in the time to perform TUG test was found between individuals with AIS having different curve severity,\(^{21}\) indicating sufficient construct validity.\(^{31}\)  

**Body Structure and Function Measures**

The Trunk Pelvis Hip Angle (TPHA) test is used to measure mobility of lumbo-pelvic-hip complex.\(^{54}\) Moderate-quality
evidence supported sufficient inter-observer reliability of TPHA (ICC > 0.942).13

The criterion validity of Modified Schober Test (MST) was rated indeterminate (Very low evidence), as not all required information reported, that is, amount of correlation with radiographs.52 While, its construct validity rated insufficient.52

The construct validity of the Fingertip To Floor Test (FTF) and 7th cervical vertebra to posterior superior iliac spine (C7-PSIS) distance was rated insufficient (moderate-quality

| TABLE 5. Summary of Findings Table for the Measurement Properties of Outcome Measure |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| **Measurement Property**        | **Outcome Measure (Subscale)** | **Summary Result** | **Overall Rating** | **Quality of Evidence** |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| Internal consistency            |                   |                 |                 |                 |
| SRS-22r (activity)              | $\alpha = 0.82$ | $\alpha = 0.82$ | $\alpha = 0.89$ | $\alpha = 0.89$ |
| Reliability                      |                   |                 |                 |                 |
| SRS-22r (activity)              | ICC $= 0.76$ (0.56–0.80) | ICC $= 0.46$ (0.29–0.63) | ICC $= 0.73$ (0.20–0.85) | ICC $= 0.73$ (0.20–0.85) |
| SAQ                             | Kappa $\kappa \geq 0.70$ | $\kappa = 0.70$ | $\kappa = 0.70$ | $\kappa = 0.70$ |
| Cross-cultural validity/measuremen |                   |                 |                 |                 |
| measurement invariance           |                   |                 |                 |                 |
| SRS-22 (activity)               | No multiple group factor analysis performed | No multiple group factor analysis performed | No multiple group factor analysis performed | No multiple group factor analysis performed |
| SRS-30 (Function/Activity)      |                   |                 |                 |                 |
| SRS-22 (Activity)               | SDC (0.24) > MIC (0.08) | SDC (0.41) > MIC (0.08) | SDC (0.41) > MIC (0.08) | SDC (0.41) > MIC (0.08) |
| SRS-24 (Function)               |                   |                 |                 |                 |
| SRS-22 (Activity)               | Two hypotheses confirmed | Two hypotheses confirmed | Two hypotheses confirmed | Two hypotheses confirmed |
| SRS-22r (Function)              |                   |                 |                 |                 |
| SRL (physical activity)         |                   |                 |                 |                 |
| PODCI (functional scales)       |                   |                 |                 |                 |
| PROMIS (Mobility)               |                   |                 |                 |                 |
| TUG test                        |                   |                 |                 |                 |
| MST, FTF Test, C7-PSIS          |                   |                 |                 |                 |
| Criterion validity              |                   |                 |                 |                 |
| MST                             | Not all information for “+” | Not all information for “+” | Not all information for “+” | Not all information for “+” |
| Responsiveness                  |                   |                 |                 |                 |
| SRS-22 (Activity)               |                   |                 |                 |                 |
| SRS-22r (Function)              |                   |                 |                 |                 |

C7-PSIS indicates cervical 7 to posterior superior iliac spine; CHQ-CF87 Child Health Questionnaire-Child Self-Report Form 87; FTF, Fingertip To Floor test; ICC, interclass correlation coefficient; LSB, lateral side bending; MIC, minimal important change; MST, Modified Schober test; PODCI, Paediatric Outcomes Data Collection Instrument; PROMIS, patient-reported outcomes measurement information system; SAQ, sport activity questionnaire; SDC, small detectable change; SQLI, scoliosis quality of life index; SRS, Scoliosis Research Society; SRS-22r, Scoliosis Research Society-22 revised; TPHA, Trunk Pelvis Hip Angle test; TUG, Timed Up and Go. $\alpha = $ Cronbach alpha, $+= $ sufficient, $\equiv =$ indeterminate, $\equiv =$ insufficient.

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No difference in scores of these tests was found between individuals with mild and severe curves. On the other hand, construct validity of lateral side bending (LSB) angle and axial rotation was sufficiently different between individuals with severe curves.

**Interpretability and Feasibility**

Information about interpretability and feasibility aspects of functional scales included in this review are available in supplemental digital content 5, http://links.lww.com/BRS/B724. The majority of these scales had high ceiling effect (20%–44%) and minimal floor effects. An exception to this is physical activity scale of SQLI (minimal ceiling and floor effects). The minimal clinical important difference (MCID) reported for activity domain for SRS-22 is 0.08. While minimum detectable measurement difference (MDMD) of activity for SRS-22r is 0.24. Review studies did not report information about response shift and percentage of missing items. Moreover, limited information found about feasibility aspects. Most of the included PROMs are completed within 2 to 3 minutes, and it could be concluded that these PROMs are easy to complete, available in different settings, and available free of charge.

**DISCUSSION**

This is the first rigorous systematic review identifying OM used to assess physical functioning in individuals with AIS and evaluating their respective measurement properties. Search one enabled the generation of a list of OM and search two revealed a few measurement properties studies; comprising nine PROMs, just one PBOM, and six measures of body structure and function. None of the identified PROMs had evidence of sufficient content validity and sufficient internal consistency. Thus, PROMs identified in this review have the potential to be recommended for use but are yet to have the measurement properties investigated. The current evidence showed limited information on the measurement properties of PBOM and body function and structure measure in individuals with AIS.

**Patient-Reported Outcome Measure**

This review highlights a gap in evidence on content validity of routinely used PROMs that evaluate physical functioning in individuals with AIS. As COSMIN suggested, content validity is the first and most important measurement property to consider when selecting any PROM. It should be assessed with an interview with both professionals and patients to assess relevance, comprehensiveness, and comprehensibility of items within a PROM. The identified PROMs lack adequate development process, as many were developed in a population whose mean age was higher than that of individuals with AIS. The physical activity scale of SQLI was the only scale where its comprehensibility had been investigated, however using healthy children it is not representative of our population of interest.

The majority of identified measurement properties’ studies tested construct validity, which displayed sufficient ratings in most of OMs. Otherwise, internal consistency was undetermined due to lack of evidence of sufficient structural validity. Most of activity scales identified demonstrated high ceiling effects, which affect its ability to assess changes in patient’s status.

**Performance-Based Outcome Measure**

Compared with PROMs just one study has investigated measurement properties of a PBOM where pain and psychological distress may influence the self-reporting of functional ability, it is questionable if PROMs are providing adequate information about actual functional performance of this population. While the TUG test assesses balance, mobility, and walking ability, more evidence-based PROM are needed to evaluate important and meaningful activities of daily livings for individuals with AIS.

**Body Structure and Function Measures**

Radiographs, measured using Cobb angle, are the gold standard measure for evaluating spinal curvature. While measurement properties of this measure have been studied before, little attention has given to other measures, such as MST and FTF test. These tests are inexpensive, easy, quick measure that does not expose young spines to ionizing radiation. When adequate measurement properties of these OM established, it could serve as a surrogate to radiographs.

**Strengths and Limitations**

This review utilized two-search strategy to enable identification of all types of OM used in AIS. Risk of selection bias was minimized by involving two independent reviewers for all stages. Adherence to the COSMIN methodology as preferred approach for systematic review of measurement properties is another strength. However, ratings of studies were determined using lowest score principle, which may underestimate a study’s final quality score. A potential limitation of this review is there are few studies investigating measurement properties in individuals with AIS, and some that were included where investigating of measurement property was not a primary aim.

**CONCLUSION**

A range of measures are used for physical functioning assessment in individuals with AIS. The majority of measurement properties studies identified were for PROM with a paucity of information on PBOM and body structure and function measures. Moreover none of the identified PROM can be recommended for use in AIS. More measurement properties studies are required to support recommendation of these measures for research and clinical practice.

**Key Points**

- A two staged search strategy was performed on all types of outcome measure for physical functioning assessment for AIS.
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