

Physical functioning in adolescents with idiopathic scoliosis

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Physical functioning in adolescents with idiopathic scoliosis: A systematic review of outcome measures and their measurement properties

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Physical functioning in adolescents with idiopathic scoliosis: A systematic review of outcome measures and their measurement properties.

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Abstract

Study Design. A systematic review

Objective. To summarise 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 outcome measures (OM) are important for precision in research and practice

Methods. A two-search strategy performed on electronic databases up to December 2019. Search one revealed list of OM were used for physical functioning assessment in AIS. Search two identified studies that evaluated measurement property in AIS; using list identified in search one. Two independent reviewers determined study eligibility, risk of bias assessment (COSMIN checklist), and data extraction. The level of evidence was established using 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 of PROM, 1 for PBOM and 3 for body structure and function measure. Construct validity, reliability and responsiveness of most PROMs 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 evaluated with variety of measures in AIS. Majority of measurement properties studies were evaluating PROM with paucity of information on measurement properties of PBOM and body structure and function OM. Based

on COSMIN methodology, none of OM identified in this review can be recommended for use in individuals with AIS.

Key Words: Systematic Review, Idiopathic Scoliosis, Physical Functioning, Outcome Assessment, Validity, Reliability, Measurement Properties.

Level of Evidence: 2

Key points

- Two searched-strategy performed on all types of outcome measure used in physical functioning assessment for Adolescent with Idiopathic Scoliosis (AIS).
- Most of studies of measurement properties were evaluating Patient Reported Outcome Measure (PROM) with paucity of information on Performance-Based Outcome Measure (PBOM), and body structure and function measures.
- Based on COSMIN methodology, none of measure identified in this review can be recommended for use in individuals with AIS.

Mini abstract

This review identified a variety of outcome measure used for physical functioning assessment in Adolescent with Idiopathic Scoliosis. However, a limited number of studies evaluated its measurement properties with focus was on patient-reported outcome measure compared to other outcome measures i.e. performance-based and body structure and function measures.

1 INTRODUCTION

2 Adolescent idiopathic scoliosis (AIS) is the most common spine deformity among children
3 aged 10 to 18 years old ¹, with prevalence ranging 1-3% ². Comprising of a lateral curvature
4 and axial rotation of spinal vertebrae, the cause is unknown in most cases ³. AIS has been linked
5 to back pain ⁴, psychological stress ⁵, and respiratory dysfunction ⁶, potentially impacting on
6 quality of life (QoL) ⁷.

7 A dimension of any QoL measurement is 'physical functioning', this being the ability to carry
8 out activities of daily living ⁸. Physical functioning limitations have been associated with an
9 increased risk of disability and predictive of social and healthcare use ⁹. Limitations include
10 walking and maintaining body positions ⁷, as well as pain related functional restriction ¹⁰.
11 Corrective surgery is used for some, necessitating a long recovery period and often associated
12 with pain and immobility in adolescence ¹¹. Measuring the impact of AIS is therefore important
13 in both research and clinical practice.

14 Physical functioning can be evaluated with Patient-Reported Outcome Measures (PROM),
15 Performance-Based Outcome Measures (PBOM), and measures of body structure and function
16 ¹². Each measure assesses different, but complementary, aspects of physical functioning ¹²,
17 with PROM for self-report, PBOM for the performance of a specific activity (e.g., chair stand
18 test) ^{12,13} and body structure and function providing anatomical data (e.g., range of motion) or
19 a physiological process (e.g., muscle strength) ¹².

20 Outcome measures need adequate measurement properties to assure truthfulness of results and
21 avoid risk of bias ¹⁴. The COnsensus-based Standards for the selection of health Measurement
22 INstruments (COSMIN) group developed a taxonomy of measurement properties to enable this
23 ¹⁵. Three main domains are validity, reliability and responsiveness ¹⁵. The COSMIN group

24 provide guidelines for conducting a systematic review for PROM, which can be adapted for
25 other OM¹⁶.

26 The Scoliosis Research Society questionnaire (SRS-22) and its' variants are the most widely
27 used PROM in this population¹⁷⁻¹⁹. From the Core Outcome Study (COS), SRS-22 revised
28 (SRS-22r) is recommended and the considered reference standard for evaluating physical
29 functioning for adolescents and young adults with spine deformity²⁰. However, SRS-22r does
30 not capture all aspects of physical functioning, such as mobility and self-care⁷. Furthermore,
31 the COS study included all forms of spinal deformities; the heterogeneity limiting applicability
32 to individuals with AIS. Furthermore, little is known about PBOM and body structure and
33 function measures for individuals with AIS.

34 In the absence of existing relevant reviews,²¹, the purpose of this review was to identify OM
35 used to assess physical functioning in individuals with AIS, and secondly to evaluate their
36 measurement properties.

37 **Methods**

38 **Design**

39 This review was conducted according to a registered (PROSPERO CRD42019142335) and
40 published protocol²². Designed in line with COSMIN methodology for systematic review of
41 PROM¹⁶, the review is reported in line with Preferred Reporting Items for Systematic Review
42 and Meta-Analysis (PRISMA) statement²³.

43 **Search strategy**

44 The search was conducted in two parts. Search one identified and generated a list of OM used
45 for assessment of physical functioning in AIS. Search two identified the studies of
46 measurement properties using the list from search one. Details of both search are listed in Table
47 1.

48 Data sources

1
2
3 49 A comprehensive search was performed using MEDLINE, PsycINFO, EMBASE, CINAHL,
4
5 50 SPORTdiscus, Web of Science and PubMed databases from date of inception until December
6
7 51 2019. As well as searches on key journals, reference lists, conference proceedings and grey
8
9
10 52 literature were also searched. The search terms were first developed for MEDLINE and then
11
12 53 adapted with relevant syntax and subject headings for the other databases. Supplemental digital
13
14
15 54 content 1 shows example of search one and two.

17 55 Study selection

16
17
18
19
20
21 56 Two independent reviewers (SA, EB) assessed studies based on the title and abstract for
22
23 57 eligibility. In case of insufficient information, full text articles were retrieved and screened for
24
25 58 eligibility. The reviewers discussed findings and reached consensus on eligibility of studies.
26
27
28 59 The percentage agreement between reviewers was estimated using the κ statistic (SPSS for
29
30 60 Windows statistical software package IBM SPSS Statistics V.25).

31 61 Data extraction

32
33
34
35
36 62 Two reviewers (SA, EB) independently extracted data of eligible studies. Information about
37
38 63 study, participants characteristics, outcome measures and measurement properties were
39
40
41 64 extracted. If information was not clear or unavailable in studies, corresponding authors were
42
43 65 contacted.

44 66 Risk of bias assessment

45
46
47
48
49 67 The risk of bias for each measurement properties was assessed using COSMIN checklist ¹⁴.
50
51 68 Adaptions were made for studies of body structure and function e.g. interobserver reliability.
52
53
54 69 This involved removal of inapplicable standards i.e. “was the time interval appropriate?” Each
55
56 70 item of measurement property was rated as either ‘very good’, ‘adequate’, ‘doubtful’ or
57
58
59 71 ‘inadequate quality’ ¹⁴. Subsequently overall methodological quality of measurement property

72 was rated based on “the worst score counts principle”¹⁴. Two independent reviewers (SA, EB)
73 assessed study quality and inconsistencies were resolved by discussion.

74 **Hypotheses for construct validity and responsiveness**

75 Hypotheses for evaluating construct validity and responsiveness assessed in included studies,
76 were pre-defined³³ and listed in supplemental digital content 2.

77 **Data analysis and synthesis**

78 The necessary homogeneity in studies results was insufficient, thus meta-analysis was not
79 performed. Results were therefore synthesised and qualitatively summarised¹⁶. The
80 measurement property for each study was rated according to updated criteria for good
81 measurement properties as sufficient (+), insufficient (–) or indeterminate (?)¹⁶. Then,
82 evidence was graded using modified Grading of Recommendations Assessment, Development
83 and Evaluation (GRADE) approach¹⁶. Five factors determine quality of evidence: risk of bias,
84 inconsistency, indirectness, imprecision and publication bias³⁴. For evaluating measurement
85 properties in systematic reviews of PROM, only four factors were assessed, with fifth factor
86 (publication bias) removed³³.

87 **RESULTS**

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

90 **Search one: inventory of outcome measure**

91 A list of OM was generated and classified into 28 PROM, 20 PBOM and 10 body structure and
92 function OM are listed in supplemental digital content 3. The International Classification of
93 Functioning, Disability and Health (ICF) model²⁵ was used to classify OM into either PBOM
94 or body structure and function OM. Agreement between reviewers (SA, EB) for title and

95 abstract assessment was excellent (94.0%, Kappa=0.91) and full-text (92.5%, Kappa=0.80).

96 The third reviewer (NRH) was consulted twice.

97 **Search two : measurement properties**

98 There were 16 studies for measurement properties of PROM, 1 study for PBOM and 3 studies
99 for body structure and function OM (Table 2). Excellent agreement between reviewers (SA,
100 EB) for titles/abstracts (95%, Kappa=0.92) and substantial agreement for full-text articles
101 (90%, Kappa=0.78)³⁵. Eleven authors responded from twenty-one who were contacted
102 clarifying participants age, language of PROM utilized, or for missing data. The third reviewer
103 (NRH) was consulted four times.

104 **Study and outcome measure characteristics**

105 Detailed information on studies and participant characteristics are shown in Table 2. The OM
106 included were 9 PROMs (6 disease-specific and 3 generic), 1 PBOM, and 6 body structure and
107 function OM. Detailed description of OMs and their characteristics are shown in Table 3 &
108 Table 4.

109 **Risk of bias**

110 Evaluated measurement properties included, development (n=1), internal consistency (n=3),
111 reliability (n=5), measurement invariance (n=2), measurement error (n=2), hypothesis testing
112 for construct validity (n=18), responsiveness (n=2). Results of risk bias assessment are
113 presented in supplemental digital content 4.

114 **Measurement properties and synthesis of evidence**

115 Table 5 shows the summary of findings table for results of measurement properties and the
116 overall evidence for measurement properties against COSMIN and GRADE approach.

117

118 Patient-reported outcome measures

1
2
3 119 Functional scales of SRS-24¹⁹ displayed sufficient discriminative validity in pre and post-
4
5 120 surgery individuals with AIS³⁸. While, construct validity of SRS-22 function scale was rated
6
7 121 insufficient (Moderate-quality evidence)^{38,40,41}, and sufficiently responsive³⁹ (very low-
8
9
10 122 quality evidence). Measurement invariance of this scale was rated indeterminate since no
11
12 123 multiple group factor analysis was performed⁴³, and the measurement error rated insufficient
13
14
15 124⁴². The activity scale of SRS-22r was rated sufficiently reliable as the Interclass Correlation
16
17 125 Coefficient (ICC) was 0.76 (0.56–0.80) supported by low-quality evidence. However, internal
18
19 126 consistency¹⁸ was rated indeterminate³³. The SRS-22r showed insufficient measurement error
20
21
22 127⁴⁵ (Moderate-quality evidence). A strong correlation between function scale of SRS-22r with
23
24 128 mobility scale of Child Health Questionnaire-Child Self-Report Form 87 (CHQ-CF87)
25
26
27 129 (Pearson $r=0.73$)¹⁸ indicating sufficient convergent validity. Whilst, hypothesis of
28
29 130 discriminative validity was not met⁴⁴. Thus, evidence for construct validity was downgraded
30
31
32 131 for inconsistency. Moreover, the scale was found unresponsiveness to change (low-quality
33
34 132 evidence)⁴⁵.

35
36
37 133 The SRS-30 consists of questions from both SRS-24 and SRS-22. Although no study was
38
39 134 identified evaluated its validity or reliability, high-quality evidence indicated that the construct
40
41
42 135 validity of activity scale of SRS-30 was sufficient⁴⁸. A difference in activity scores (0.50)
43
44 136 observed at instrumentations construct before and after surgery⁴⁸, whilst measurement
45
46
47 137 invariance was rated indeterminate⁴⁷.

48
49 138 Scoliosis Quality of Life Index (SQLI) is a modified version of SRS-22 consisting of physical
50
51
52 139 activity domain³⁶. Very low evidence demonstrated that its content validity is sufficient based
53
54 140 on reviewers' ratings only⁷⁹. The questionnaire was tested for comprehensibility among
55
56
57 141 healthy school children (9.9 years old) only³⁶. Per COSMIN guidance, those children may not
58
59 142 consider as representative to population of interest⁷⁹. The internal consistency of activity scale

143 was rated indeterminate, while its reliability was insufficient (ICC =0.46, 0.29 –0.63). The
144 evidence was downgraded due to serious risk of bias and imprecision. Moderate-quality
145 evidence showed that construct validity of this scale was sufficient.

146 Mobility scale of Patient-Reported Outcomes Measurement Information System (PROMIS)⁴⁶
147 correlated with function scale of SRS-22r (Pearson $r=0.65$)⁴⁶ indicating sufficient construct
148 validity, while functional domains of Paediatrics Outcomes Data Collection Instrument
149 (PODCI) had insufficient construct validity⁵⁰.

150 Internal consistency of physical functioning scale of (CHQ-CF87)¹⁸ rated indeterminate as
151 evidence of sufficient structural validity is not available³³, while its reliability scale was
152 sufficient (ICC = 0.73, 0.20– 0.85) based on low-quality evidence.

153 The Sport Activity Questionnaire (SAQ) was developed based on a test-retest method, which
154 is considered a reliability study based on COSMIN definitions¹⁵. A very low-quality evidence
155 showed that reliability of SAQ was sufficient.

156 In conclusion, according to COSMIN methodology for a PROM to be recommended for use,
157 it should exhibit any level of sufficient content validity and low level of evidence of sufficient
158 internal consistency³³. None of the identified PROMs in this review met these criteria, thus we
159 are unable to recommend any of these PROMs for use in individuals with AIS. Furthermore,
160 none of these PROM had a high evidence of insufficient measurement properties. Therefore,
161 these PROMs can be used but it require further assessment of the quality of its measurement
162 properties to be recommended for use with individuals with AIS³³.

163 **Performance-based outcome measure**

164 Timed Up and Go Test (TUG) is the only performance measure identified in this review, its
165 measurement properties tested in AIS. A difference in the time to perform TUG test was found
166 between individuals with AIS having different curve severity⁵¹, indicating sufficient construct
167 validity⁵¹.

168 **Body structure and function measures**

169 The Trunk Pelvis Hip Angle (TPHA) test is used to measure mobility of lumbo-pelvic-hip

170 complex⁵⁴. Moderate -quality evidence supported sufficient inter-observer reliability of TPHA

171 (ICC > 0.942)³³.

172 Very low evidence showed that criterion validity of Modified Schober Test (MST)⁵² rated

173 indeterminate as not all required information reported i.e. amount of correlation with

174 radiographs⁵². While, its construct validity rated insufficient⁵².

175 The construct validity of Fingertip To Floor Test (FTF) and 7th cervical vertebra to Posterior

176 Superior Iliac Spine (C7-PSIS) distance was rated insufficient (moderate-quality evidence)⁵³.

177 No difference in scores of these tests was found between individuals with mild and severe

178 curves⁵³. On the other hand, construct validity of Lateral Side Bending (LSB) angle and Axial

179 Rotation was sufficiently different between individuals with severe curves⁵³.

180 **Interpretability and feasibility**

181 Information about interpretability and feasibility aspects of functional scales included in this

182 review are available in supplemental digital content 5. The majority of these scales had high

183 ceiling effect (20% -44%) and minimal floor effects. An exception to this is physical activity

184 scale of SQLI (minimal ceiling and floor effects)^{36,37}. The Minimal Clinical Important

185 Difference MCID reported for activity domain for SRS-22 is 0.08⁴². While Minimum

186 Detectable Measurement Difference (MDMD) of activity for SRS-22r is 0.24⁴⁵. Review

187 studies did not report information about response shift and percentage of missing items.

188 Moreover, limited information found about feasibility aspects. Most of the included PROMs

189 are completed within 2-3 minutes, and it could be concluded that it these PROMs are easy to

190 complete, available in different settings, and available free of charge.

191

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 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 [34]. 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 PROM⁷⁹. It should be assessed with an interview with both professionals and patients to assess relevance, comprehensiveness, and comprehensibility of items within a PROM⁷⁹. 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^{17,19,66,80}. The physical activity scale of SQLI was the only scale where its comprehensibility had been investigated³⁶, however using healthy children³⁶ it is not representative of our population of interest⁷⁹.

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 status³⁶.

217 **Performance-based outcome measure**

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3 218 Compared with PROMs just 1 study has investigated measurement properties of a PBOM⁵¹
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5 219 Where pain¹⁰ and psychological distress⁸¹ may influence the self-reporting of functional
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7 220 ability¹², it is questionable if PROMs are providing adequate information about actual
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10 221 functional performance of this population. Whilst the TUG test assesses balance, mobility, and
11
12 222 walking ability⁵¹, more evidence-based PBOM are needed to evaluate important and
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15 223 meaningful activities of daily livings for individuals with AIS.

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18 224 **Body structure and function measures**

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21 225 Radiographs, measured using Cobb angle, are the gold standard measure for evaluating spinal
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23 226 curvature²⁴. While measurement properties of this measure have been studied before²⁷, little
24
25 227 attention has given to other measures, such as MST and FTF test. These tests are inexpensive,
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28 228 easy, quick measure that does not expose young spines to ionising radiation. When adequate
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30 229 measurement properties of these OM established, it could serve as a surrogate to radiographs.

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33 230 **Strengths and limitations**

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35 231 This review utilized two-search strategy to enable identification of all types of OM used in
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38 232 AIS. Risk of selection bias was minimized by involving two independent reviewers for all
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40 233 stages. Adherence to the COSMIN methodology as preferred approach for systematic review
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42 234 of measurement properties is another strength [33]. However, ratings of studies were
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45 235 determined using lowest score principle, which may underestimate a study's final quality score
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48 236 [14]. A potential limitation of this review is there are few studies investigating measurement
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50 237 properties in individuals with AIS, and some that were included where investigating of
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52 238 measurement property was not a primary aim.

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55 239 **CONCLUSION**

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58 240 A range of measures are used for physical functioning assessment in individuals with AIS.
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60 241 The majority of measurement properties studies identified were for PROM with a paucity of

242 information on PBOM and body structure and function measures. Moreover none of identified

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243 PROM can be recommended for use in AIS. More measurement properties studies are required

244 to support recommendation of these measures for research and clinical practice.

245

246 **List of Supplemental Digital Contents**

247 Supplemental Digital Content 1. docx

248 Supplemental Digital Content 2. docx

249 Supplemental Digital Content 3. docx

250 Supplemental Digital Content 4. docx

251 Supplemental Digital Content 5. docx

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| Table 1: Search one and search two strategy | | |
|--|---|--|
| | Search one (Inventory of outcome measure) | Search two (Measurement properties) |
| <i>Inclusion criteria</i> | <ul style="list-style-type: none"> Individuals with AIS ($\geq 10^\circ$ Cobb angle) ¹ Age 10-18 years old | <ul style="list-style-type: none"> Individuals with AIS ($\geq 10^\circ$ Cobb angle) ¹ Age 10-18 years old Mixed cohort studies >50% of participants with AIS |
| | <ul style="list-style-type: none"> 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. | <ul style="list-style-type: none"> Measurement properties studies (i.e. content validity, structural validity, construct validity, reliability, and responsiveness) of outcome measure identified in search one. |
| | <p>Outcome measure defined as following:</p> <ul style="list-style-type: none"> 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 ², 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” ^{12,25}. | |
| <i>Exclusion criteria</i> | <ul style="list-style-type: none"> Radiographs, laboratory- based measures, anthropometric measures ³⁻⁹. | <ul style="list-style-type: none"> Studies in non-English speaking population Systematic reviews Studies providing normative data Studies providing indirect evidence on measurement properties. |

AIS indicates Adolescent Idiopathic scoliosis; PROM, Patient Reported Outcome Measure; PBOM, Performance Based Outcome Measure.

| Table 2: Studies and participants characteristics | | | | | | | | | |
|---|----------------|---------|-------------------------|----------------|-----------------|---|---|---|---|
| Patient Reported Outcome Measure | | | | | | | | | |
| 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 <i>et al.</i> ³⁶ | SQLI | Canada | 14.9 ± 2.4 (10-18) | F(70) M(14) | 84 | NR | Unbraced 26.1° ± 10° Braced 34.3° ± 8.7° Postsurgical 31.0° ± 11.4° | Postsurgical (16) Braced (30) Unbraced (24) Control (14) | 81.1 ± 15.7 |
| Parent <i>et al.</i> ³⁷ | SQLI | Canada | 14.7 ± 1.9 (8-20) | F(95) | 95 | Main thoracic (29) Double thoracic (4) Double major (23) Triple major (2) Thoracolumbar/lumbar (20) Thoracolumbar/lumbar, main thoracic (17) | <30° (34) 30°-50° (44) >50° (17) | Surgery | NR |
| Bastrom <i>et al.</i> ³⁸ | 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%) | Pre-surgery 55° ± 13 Post surgery 20° ± 9 | Pre and Post-surgery | Pre-surgery 45° Cobb SRS-22 (4.6 ± 0.5) SRS-24 (4.1 ± 0.5) >80° Cobb SRS-22 (4.2 ± 0.7) SRS-24 (3.8 ± 0.7) Post-surgery <11° Cobb SRS-22 (4.6 ± 0.5) SRS-24 (4.17 ± 0.5) >29° Cobb SRS-22 (4.61 ± 0.5) SRS-24 (4.17 ± 0.6) |

| | | | | | | | | | |
|-------------------------------------|---------|----------------|---|---|---|---|--|---|---|
| Asher <i>et al.</i> 39 | SRS-22 | USA | 16.4 (10.6 – 47.3) | F(48) M(10) | 58 | Single (36) Double (19) Triple (3) | 63° | Surgery | Function (0 months) 4.1 Function (3 months) 3.3 Function (6 months) 3.9 Function (12 months) 4.2 Function (24 months) 4.3 |
| Asher <i>et al.</i> 40 | SRS-22 | USA | Control 13 (10.7- 15.4) Non-surgical 14 (9.9 -16) Non-surgical untreated 14 (10.8-16) Non-surgical braced 13 (9.9 -15.2) Pre-surgery 14 (10.6–15.8) | Control F(15) M (4) Non- surgical F(57) M(11) Non- surgical untreated F(44) M(10) Non- surgical braced F(13) M(1) Pre- surgery F(31) M(1) | Total (119) Control (19) Nonsurgical (68) Untreated (54) Braced (14) Pre-surgery (32) | Thoracic, Thoracolumbar, Lumbar; double Triple | Largest cobb angle Non-surgical untreated 27° Braced 31° Pre-surgery 61° | Brace, pre-surgery, control | Control (4.5±0.35) Nonsurgical (4.4±0.36) Non-surgical untreated (4.4±0.37) Non- surgical braced (4.5±0.32) Pre-surgery (4.2±0.42) |
| Parent <i>et al.</i> 41 | SRS-22 | Canada | 13.5–20 (153) Total (18.6 ± 9.2) | F(153) | 153 | NR | 30° (58) 30°–50°(66) 50° (4) | Observation (107) Brace(32) Pre-surgery (22) Post-surgery (62) | Observation (4.3 ± 0.59) Brace (4.5 ± 0.59) Pre-surgery (4.2 ± 0.58) Post-surgery (4.1 ± 0.60) |
| Carreon <i>et al.</i> 42 | SRS-22 | USA | 14.3 ± 1.9 (10 –18) | F(735) M(152) | 887 | NR | 53°±18° | Pre & 1 year post-surgery | Pre-surgery 4.15 ± 0.55 Post-surgery 4.23 ± 0.46 |
| Verma <i>et al.</i> 43 | SRS-22 | USA & Ghana | 15.4 | F(100) M(60) | 160 | NR | Ghana 67.2° USA 52° | Pre-surgery | Ghana 3.7 ± 0.8 USA 4.2 ± 0.4 |
| Berliner <i>et al.</i> 44 | SRS-22r | USA | 13.8 (11.0 - 17.2) | F(115) M(40) | 155 | Non-surgical Thoracic (56.5%) Thoracolumbar (38.7%) Lumbar (4.8%) | Total 43.1° Non-surgical 21.9° Presurgical 57.2° | Non-surgical & pre- surgical | 0° –19° (4.5± 0.47) 20° –40° (4.4 ± 0.37) 41° –50° (4.1± 0.69) |

| | | | | | | | | | |
|--|--------------------------|------------------|---|---|--------------------------|---|---|--|---|
| | | | | | | Pre-surgical Thoracic (65.2%) Thoracolumbar (34.8%) Lumbar (0%) | | | 51°–60° (4.2 ± 0.54) >60° (4.3 ± 0.55) |
| Kelly et al. ⁴⁵ | SRS-22r | USA | 14.6 (10–22) | F(1,034) M(247) | 1,281 | Lenke 1(552) Lenke 2 (272) Lenke 3 (93) Lenke 4 (46) Lenke 5 (196) Lenke 6 (120) | NR | 1, 2year Post-Surgery | Activity MCID (0.08) MDMD (0.24) |
| Glattes et al. ¹⁸ | SRS-22r, CHQ- CF87 | USA | 14.1 ± 2.7 (8-18) | F(58) M(12) | Total (70) | NR | 29.8° ± 12.3° | Pre-surgery | SRS-22r (4.5±0.65) CHQ-CF87 (91±15.6) |
| Fedorak et al. ⁴⁶ | PROMIS, SRS22r | USA | 14.4 ±2.1 (11.4–17.4) | F(78.8%) M(21.2%) | 113 | Thoracic (67%) Thoracolumbar (21.7%) Lumbar(11.3%) | Thoracic kyphosis °34.1 ±14.9 Lumbar lordosis 54.8°±13.3 | Observed, Pre or post- bracing (69.0%) Brace (27.4%) Surgery (3.5%) | PROMIS, Mobility (50.93 ±9.80) SRS-22r, Function (4.5±0.5) |
| Roberts et al. ⁴⁷ | SRS-30 | USA | F (14.0) M (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°) | Pre-surgery, 2yr. post- surgery | Pre-surgery F (4.2) M (4.2) Post-surgery F (4.3) M (4.4) |
| Lubicky et al. ⁴⁸ | SRS-30 | USA | 15.6 ±1.7 | F(75%) | 356 | NR | NR | Pre-surgery, 2yr. post- surgery | Pre-surgery (4.18 ± 0.55) Post-surgery (4.34 ± 0.51) |
| Sarwahi et al. ⁴⁹ | SAQ | USA | 15 (13 –17) | F(71) M(24) | 95 | NR | Pre-surgery 51.08° Post-surgery 15.98° | NR | NR |
| Lerman et al. ⁵⁰ | PODCI | North America | Parent 15.2 (11.7– 18.8) Patient 15.3 (11.7– 20.9) | Parent F(88) M(9) Patient F(86) M(9) | 102 | Thoracic (17) Thoracolumbar (6) Lumbar(7) Double curve (17) | 10-29° (n=23) 30-49° (n=20) >50°(n=4) | 1 year Post surgery | 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. ⁵¹ | 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 Thoracolumbar | Mild AIS 19.9°±4.3 Moderate AIS 31.8°±4.2 Severe AIS 53.4°±16.1 | Pre-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. ⁵² | MST | USA | 14.2 ± 1.9 (11.3-18.6) | F(37) | 37 | Thoracic Lumbar | Thoracic 40°±20° Lumbar 31°±12° | Pre-treatment | 5.7 ± 2.2 cm |
| Eyvazov et al. ⁵³ | MST FTF test, Axial rotation, LSB, ΔC7-PSIS | China | 15.7 ± 4.1 | M(12) F(46) | 58 | Lenke 5 (Thoracolumbar/ lumbar) | Group A 25° ± 7.1° Group B 49.8° ± 13.6° Tot 34° ± 9.2° | Pre-treatment | Modified Schober's (cm) Group A: (20.6 ± 1.4) Group B: (20.3 ± 1.2) FTF test (cm) Group A : (10.1 ± 11.2) Group B: (11 ± 10.3) ΔC7-PSIS (27.6 ± 1.8%) LSB (degrees) Group A: (66.6 ± 13.4) Group B: (57.8 ± 14.3) Axial rotation (degrees) Group A: (90.1 ± 21.9) Group B: (5.9 ± 19.6) |
| Stepien et al. ⁵⁴ | 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° ± 13.4° Lumbar 25.8° ± 10.5° | Physiotherapy | AIS Left TPHA -10.93° ± 4.64° Right TPHA -2.37° ± 8.30° Control Left TPHA -11° ± 3.30° Right TPHA -8.64° ± 4.70° |
| <p><small>AIS indicates Adolescent Idiopathic scoliosis; CHQ-CF87, Child Health Questionnaire- Child Self-Report Form 87; C7-PSIS, Cervical 7 to Posterior Superior Iliac Spine; F, Female ;FTF, 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; SRS, Scoliosis Research Society; SRS-22r, Scoliosis Research Society-22Revised; SQLI, Scoliosis Quality of Life Index; TPHA, Trunk Pelvis Hip Angle test; TUG, Timed Up and Go Test; USA, United State of America.</small></p> | | | | | | | | | |

Table 3: Patient-reported outcome measures characteristics

| PROMS | Country | Sub-scale items(n) | Target population | Mode of administration | Recall period | Response options | Scoring system | Available translations |
|------------------------|---------------|--|--|---|-------------------|---|--------------------------------------|---|
| SRS-24 ¹⁹ | USA | General Function (3) Function after surgery (2) Function-activity (3) | AIS | Self- administrated | Now, post-surgery | 5 response options | 1-5 | - |
| SRS-22 ³⁹ | USA | Function/Activity (5) | AIS | Self- administrated | Now, post-surgery | 5 response options | 1-5 | Turkish ⁵⁵ , Italian ⁵⁶ , Spanish ⁵⁷ , Japanese ⁵⁸ , Traditional Chinese ⁵⁹ , Simplified Chinese ⁶⁰ , Polish ⁶¹ , French ^{62,63} , Thai ⁶⁴ , Norwegian ⁶⁵ |
| SRS-22r ⁶⁶ | USA | Function/Activity (5) | AIS | Self- administrated | Now, post-surgery | 5 response options | 1-5 | German ⁶⁷ , Greek ⁶⁸ , Dutch ⁶⁹ , Chinese ⁵⁹ , Brazilian ⁷⁰ , Italian ⁷¹ , Thai ⁷² , Arabic ⁷³ , Persian ⁷⁴ , Swedish ⁷⁵ |
| SRS-30 ⁷⁶ | USA | Function/Activity (5) post-surgery questions (2) | AIS | Self- administrated | Now, post-surgery | Function/Activity (5 response options) Post-surgery (3 response options) | Function (1-5) post-surgery (1-3) | Finnish ⁷⁷ Brazilian ⁷⁸ |
| CHQ-CF87 ¹⁸ | USA | Physical Functioning (9) | Generic | Self- administrated | NR | 4, 5, 6 Response options | 0-100 | - |
| SQLI ³⁶ | Canada | Physical activity (5) | AIS | Self- administrated | Four weeks | 5 Response options | 0-4 | - |
| SAQ ⁴⁹ | USA | Total (24) School, Gym, Carry backpack, Bend over, Running | AIS | Self- administrated | Post-surgery | NR | NR | - |
| PROMIS ⁴⁶ | USA | Mobility | Generic | Self- administrated | 7-day | 5 response options | Mean T-score 50, SD 10 | - |
| PODCI ⁵⁰ | North America | Upper Extremity Functioning , Transfers& basic Mobility Sport & Physical Function Global function | Generic Paediatric orthopaedic conditions | Self-administrated Parent-report Adolescents report | NR | 3-6 | 0-100 | - |

AIS indicates Adolescent Idiopathic scoliosis; CHQ-CF87, Child Health Questionnaire- Child Self-Report Form 87; NR, Not Reported; PODCI, Paediatrics Outcomes Data Collection Instrument; PROMIS, Patient-Reported Outcomes Measurement Information System; SAQ, Sport Activity Questionnaire; SD, Standard Deviation; SRS, Scoliosis Research Society; SRS-22r, Scoliosis Research Society-22revised; SQLI, Scoliosis Quality of Life Index; USA, United State of America.

Table 4: Performance-based and Body structure & function outcome measure characteristics

| Outcome measure (Reference) | Activity | Required Equipment | Number of trials | Parameter measured |
|---------------------------------------|--|---------------------------------|----------------------------------|--|
| TUG ⁵¹ | Stand from chair, walk 3m, return, sit down | Chair, stopwatch, walking space | 3 trials | Average of time in seconds |
| MS Test ^{52,53} | Marks on PSIS, keep knees straight, bend forward and touch the floor | Tape measure | 2-3 trials | Average of distance in cm |
| FTF test ⁵³ | Stood upright, bend forward and touch the floor | Tape measure | 2 trials | Average of distance in cm |
| C7-PSIS distance ⁵³ | Stand upright, maximally flex and extend neck, distance measured between C7 spinous process and PSIS | Tape measure | 2 trials | Average of distance in cm |
| LSB angles ⁵³ | In upright posture, knees straight, bend to the side without rotation | Goniometer | 2 trials | Average angle in degrees between lines joining PSIS and C7 |
| Axial rotation ⁵³ | Seated position, locked both arms in front of body with fixed pelvic, shoulder rotation controlled by a goniometer holder device | Goniometer | 2 trials on left and right side | Average angle in degrees |
| TPHA ⁵⁴ | Supine, flex & 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; PBOM, Performance Based Outcome Measure; TPHA, Trunk Pelvis Hip Angle test; TUG, Timed Up and Go test.

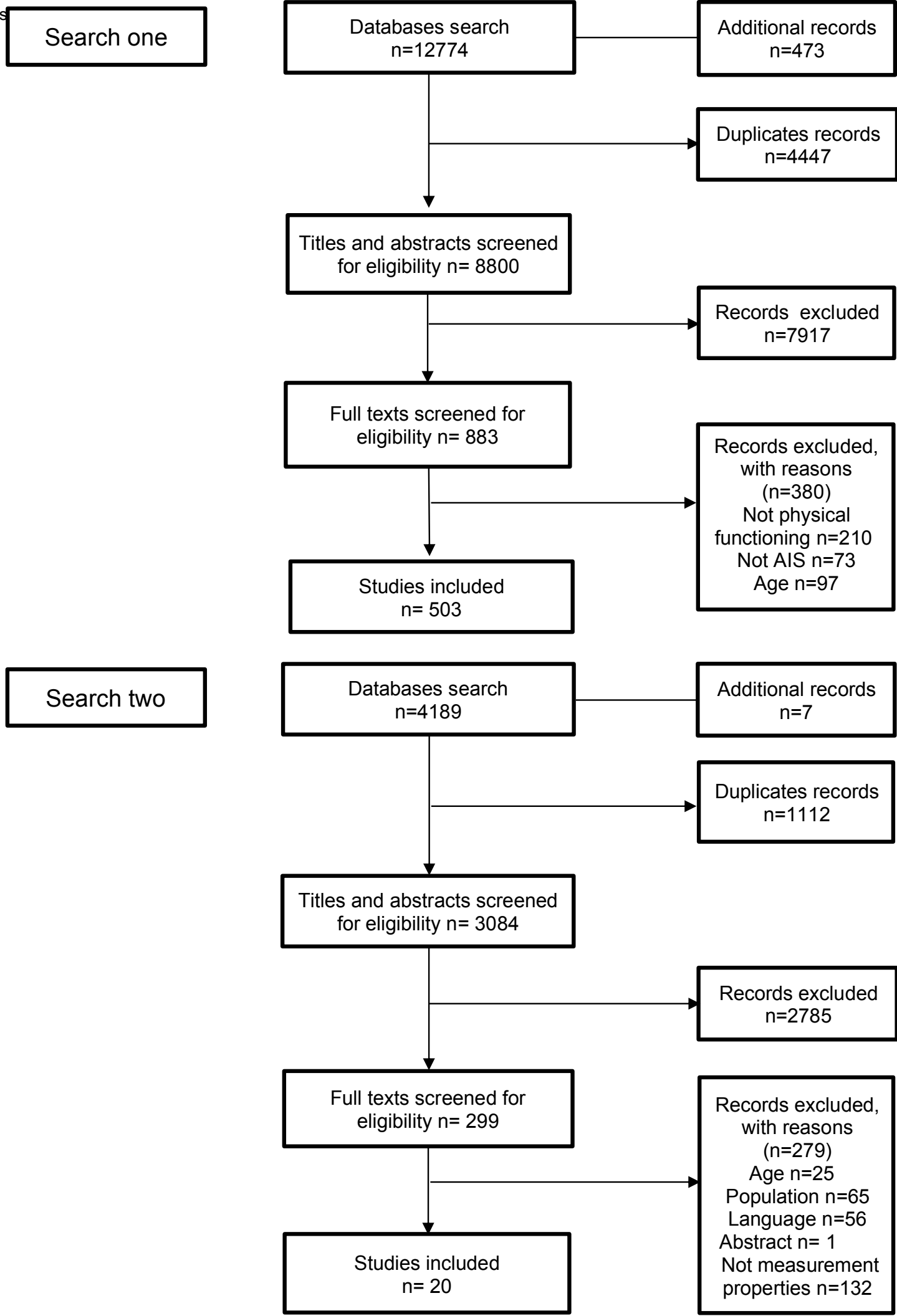
Table 5: Summary of findings table for the measurement properties of outcome measure

| Measurement property | Outcome measure (Subscale) | Summary result | Overall rating | Quality of evidence |
|---|------------------------------|---|----------------|---|
| Internal consistency | SRS-22r (Activity) | $\alpha = 0.82$ | ? | Moderate (Imprecision) |
| | SQLI (Physical activity) | $\alpha = 0.82 (0.76-0.88)$ | ? | Moderate (Imprecision) |
| | CHQ-CF87 (Physical function) | $\alpha = 0.89$ | ? | Moderate (Imprecision) |
| Reliability | SRS-22r (Activity) | ICC=0.76 (0.56- 0.80) | + | low (One study adequate quality, Imprecision) |
| | SQLI (Physical activity) | ICC= 0.46 (0.29 -0.63) | - | Low (One study adequate quality, Imprecision) |
| | CHQ-CF87 (Physical function) | ICC=0.73 (0.20- 0.85) | + | Low (One study adequate quality, Imprecision) |
| | SAQ | Kappa k ≥ 0.70 | + | Very low (One study of doubtful quality) |
| | TPHA Test | ICC= 0.85 (0.95-0.98) | + | Moderate (Imprecision) |
| Cross- cultural validity\ measurement invariance | SRS-22 (Activity) | No multiple group factor analysis performed | ? | Very low (one study inadequate quality, Imprecision) |
| | SRS-30 (Function/Activity) | No multiple group factor analysis performed | ? | Moderate (one study adequate quality) |
| Measurement error | SRS-22 (Activity) | SDC (0.24) >MIC(0.08) | - | Moderate (one study of adequate quality) |
| | SRS-22r | SDC (0.41)> MIC(.08) | - | Moderate (one study of adequate quality) |

| | | | | |
|--|---------------------------|--------------------------------------|---|---|
| Construct validity | SRS-24 (Function) | 2 hypotheses confirmed | + | High (One study very good quality) |
| | SRS-22 (Activity) | 2 out of 9 hypotheses confirmed | - | Moderate (Inconsistency) |
| | SRS-22r (Function) | 4 hypotheses confirmed | + | Moderate (Inconsistency) |
| | SRS-30 (Function) | 1 hypothesis confirmed | + | High (One study very good quality) |
| | SQLI (Physical activity) | 2 hypotheses confirmed | + | Moderate (Imprecision) |
| | PODCI (functional scales) | 2 hypotheses out of 5 confirmed | - | Moderate (One study adequate quality) |
| | PROMIS (Mobility) | 1 hypothesis confirmed | + | Moderate (One study adequate quality) |
| | TUG test | 2 hypotheses out of 3 confirmed | + | Moderate (One study adequate quality) |
| | MST, FTF Test, C7-PSIS | 3 hypotheses not confirmed | - | Moderate (Imprecision) |
| | LSB ,Axial rotation | 2 hypotheses confirmed | + | Moderate (Imprecision) |
| Criterion validity | MST | Not all information for '+' reported | ? | Moderate |
| Responsiveness | SRS-22 (Activity) | 4 hypotheses confirmed | + | Very low (One study of doubtful quality, Imprecision) |
| | SRS-22r (Function) | 1 hypothesis not confirmed | - | Low (One study doubtful quality) |
| <p><i>CHQ-CF87 indicates Child Health Questionnaire- Child Self-Report Form 87; C7-PSIS,Cervical 7 to Posterior Superior Iliac Spine; FTF, Fingertip To Floor Test; ICC, Interclass Correlation Coefficient; LSB, Lateral Side Bending; MIC, Minimal Important Change; MST,Modified Schober Test, PODCI: Paediatrics Outcomes Data Collection Instrument, PROMIS: Patient-Reported Outcomes Measurement Information System, SAQ: Sport Activity Questionnaire, SDC:Small Detectable Change, SRS: Scoliosis Research Society, SRS-22r: Scoliosis Research Society-22Revised, SQLI: Scoliosis Quality of Life Index, TPHA: Trunk Pelvis Hip Angle test, TUG: Timed Up and Go, α=Cronbach alpha, + = Sufficient, ? = Indeterminate, - = Insufficient.</i></p> | | | | |

Figures legends

Figure 1: PRISMA flow diagram of both searches and selection process





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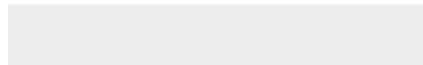
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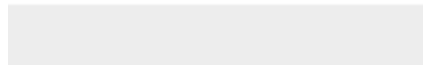
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Physical functioning in adolescents with idiopathic scoliosis: A systematic review of outcome measures and their measurement properties.

- Two searched-strategy performed on all types of outcome measure used in physical functioning assessment for Adolescent with Idiopathic Scoliosis (AIS).
- Most of studies of measurement properties were evaluating Patient Reported Outcome Measure (PROM) with paucity of information on Performance-Based Outcome Measure (PBOM), and body structure and function outcome measures.
- Based on COSMIN methodology, none of measure identified in this review can be recommended for use in individuals with AIS.