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Alamrani, Samia; Rushton, Ali; Gardner, Adrian; Bini, Elena; Falla, Deborah; Heneghan, Nicola

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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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Corresponding Author:	Samia Alamrani, MSc University of Birmingham Birmingham, West Midland UNITED KINGDOM
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	University of Birmingham
Corresponding Author's Secondary Institution:	
First Author:	Samia Alamrani, MSc
First Author Secondary Information:	
Order of Authors:	Samia Alamrani, MSc
	Alison B Rushton, EdD
	Elena Bini, MSc
	Adrian Gardner, PhD
	Deborah Falla, PhD
	Nicola R Heneghan, PhD
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Physical functioning in adolescents with idiopathic scoliosis: A systematic review of outcome measures and their measurement properties.

Samia Alamrani (MSc)[1, 2], Alison B Rushton (EdD) [1,3], Elena Bini (MSc)[1], Adrian Gardner (PhD) [4], Deborah Falla (PhD) [1], Nicola R Heneghan (PhD) [1]

[1] Centre of Precision Rehabilitation for Spinal Pain (CPR Spine), School of Sport, Exercise and Rehabilitation Sciences, College of Life and Environmental Sciences, University of Birmingham, Birmingham, United Kingdom

[2] Physical Therapy Department, College of Applied Medical Science, University of Tabuk, Tabuk, Saudi Arabia

[3] School of Physical Therapy, Western University, London, Ontario ,Canada

[4] Spine Unit, The Royal Orthopaedic Hospital, Northfield, Birmingham, United Kingdom

Address correspondence and reprint requests to Samia Alamrani, PT, MSc, PhD student at Centre of Precision Rehabilitation for Spinal Pain (CPR Spine), School of Sport, Exercise and Rehabilitation Sciences, College of Life and Environmental Sciences, University of Birmingham, Birmingham, United Kingdom. E-mail: sxa1258@student.bham.ac.uk; salamrani@ut.edu.sa

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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.

INTRODUCTION

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

A dimension of any QoL measurement is 'physical functioning', this being the ability to carry out activities of daily living [8]. Physical functioning limitations have been associated with an increased risk of disability and predictive of social and healthcare use [9]. Limitations include walking and maintaining body positions [7], as well as pain related functional restriction [10]. Corrective surgery is used for some, necessitating a long recovery period and often associated with pain and immobility in adolescence [11]. 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 [12]. Each measure assesses different, but complementary, aspects of physical functioning [12], with PROM for self-report, PBOM for the performance of a specific activity (e.g., chair stand test) [12,13] and body structure and function providing anatomical data (e.g., range of motion) or a physiological process (e.g., muscle strength) [12].

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

provide guidelines for conducting a systematic review for PROM, which can be adapted for other OM [16].

The Scoliosis Research Society questionnaire (SRS-22) and its' variants are the most widely used PROM in this population [17-19]. 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 [20]. However, SRS-22r does not capture all aspects of physical functioning, such as mobility and self-care [7]. 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, [21]. 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 [22]. Designed in line with COSMIN methodology for systematic review of PROM [16], the review is reported in line with Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement [23].

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 shows example of search one and two.

Study selection

Two independent reviewers (SA, EB) 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 (SPSS for Windows statistical software package IBM SPSS Statistics V.25).

Data extraction

Two reviewers (SA, EB) 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 [14]. Adaptions were made for studies of body structure and function e.g. interobserver reliability. This involved removal of inapplicable standards i.e. "was the time interval appropriate?" Each item of measurement property was rated as either 'very good', 'adequate', 'doubtful' or 'inadequate quality' [14]. Subsequently overall methodological quality of measurement property

was rated based on "the worst score counts principle"[14]. Two independent reviewers (SA, EB) 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 [33] and listed in supplemental digital content 2.

Data analysis and synthesis

The necessary homogeneity in studies results was insufficient, thus meta-analysis was not performed. Results were therefore synthesised and qualitatively summarised [16]. The measurement property for each study was rated according to updated criteria for good measurement properties as sufficient (+), insufficient (–) or indeterminate (?) [16]. Then, evidence was graded using modified Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach [16]. Five factors determine quality of evidence: risk of bias, inconsistency, indirectness, imprecision and publication bias [34]. For evaluating measurement properties in systematic reviews of PROM, only four factors were assessed, with fifth factor (publication bias) removed [33].

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. The International Classification of Functioning, Disability and Health (ICF) model [25] was used to classify OM into either PBOM or body structure and function OM. Agreement between reviewers (SA, EB) for title and

abstract assessment was excellent (94.0%, Kappa=0.91) and full-text (92.5%, Kappa=0.80). The third reviewer (NRH) was consulted twice.

Search two : measurement properties

There were 16 studies for measurement properties of PROM, 1 study for PBOM and 3 studies for body structure and function OM (Table 2). Excellent agreement between reviewers (SA, EB) for titles/abstracts (95%, Kappa=0.92) and substantial agreement for full-text articles (90%, Kappa=0.78) [35]. Eleven authors responded from twenty-one who were contacted clarifying participants age, language of PROM utilized, or for missing data. The third reviewer (NRH) 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 9 PROMs (6 disease-specific and 3 generic), 1 PBOM, and 6 body structure and function OM. Detailed description of OMs and their characteristics are shown in Table 3 & Table 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.

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 [19] displayed sufficient discriminative validity in pre and post-surgery individuals with AIS [38]. While, construct validity of SRS-22 function scale was rated insufficient (Moderate-quality evidence) [38,40,41], and sufficiently responsive [39] (very low-quality evidence). Measurement invariance of this scale was rated indeterminate since no multiple group factor analysis was performed [43], and the measurement error rated insufficient [42]. 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 [18] was rated indeterminate [33]. The SRS-22r showed insufficient measurement error [45] (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)[18] indicating sufficient convergent validity. Whilst, hypothesis of discriminative validity was not met [44]. Thus, evidence for construct validity was downgraded for inconsistency. Moreover, the scale was found unresponsiveness to change (low-quality evidence) [45].

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 [48], whilst measurement invariance was rated indeterminate [47].

Scoliosis Quality of Life Index (SQLI) is a modified version of SRS-22 consisting of physical activity domain [36]. 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 require 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, 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 [51], indicating sufficient construct validity [51].

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) [33].

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

The construct validity of Fingertip To Floor Test (FTF) and 7th cervical vertebra to Posterior Superior Iliac Spine (C7-PSIS) distance was rated insufficient (moderate-quality evidence) [53]. No difference in scores of these tests was found between individuals with mild and severe curves [53]. On the other hand, construct validity of Lateral Side Bending (LSB) angle and Axial Rotation was sufficiently different between individuals with severe curves [53].

Interpretability and feasibility

Information about interpretability and feasibility aspects of functional scales included in this review are available in supplemental digital content 5. 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) [36,37]. The Minimal Clinical Important Difference MCID reported for activity domain for SRS-22 is 0.08 [42]. While Minimum Detectable Measurement Difference (MDMD) of activity for SRS-22r is 0.24 [45]. 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 2-3 minutes, and it could be concluded that it 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 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 PROM [79]. It should be assessed with an interview with both professionals and patients to assess relevance, comprehensiveness, and comprehensibility of items within a PROM [79]. 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 investigated [36], however using healthy children [36] it is not representative of our population of interest [79].

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 [36].

Performance-based outcome measure

Compared with PROMs just 1 study has investigated measurement properties of a PBOM [51] Where pain [10] and psychological distress [81] may influence the self-reporting of functional ability [12], it is questionable if PROMs are providing adequate information about actual functional performance of this population. Whilst the TUG test assesses balance, mobility, and walking ability [51], more evidence-based PBOM 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 [24]. While measurement properties of this measure have been studied before [27], 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 ionising 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 [33]. However, ratings of studies were determined using lowest score principle, which may underestimate a study's final quality score [14]. 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 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.

List of Supplemental Digital Contents

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Tables

Table 1: Search one and search two strategy

	Search one (Inventory of outcome measure)	**Search two (Measurement properties)**
Inclusion criteria	• Individuals with AIS (≥10° Cobb angle) [1] • Age 10-18 years old	• Individuals with AIS (≥10° 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 [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.]	
Exclusion criteria	• Radiographs, laboratory- based measures, anthropometric measures [3-9].	• 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 *et al.* [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 *et al*. [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 *et al.* [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 *et al.* [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 *et al.* [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 *et al.* [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 *et al.* [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 *et al.* [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 *et al.* [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°

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, Modfied 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.

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, Modfied 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)	$\propto = 0.82$	?	Moderate (Imprecision)
	SQLI (Physical activity)	$\propto = 0.82$ (0.76–0.88)	?	Moderate (Imprecision)
	CHQ-CF87 (Physical function)	$\propto = 0.89$	?	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)

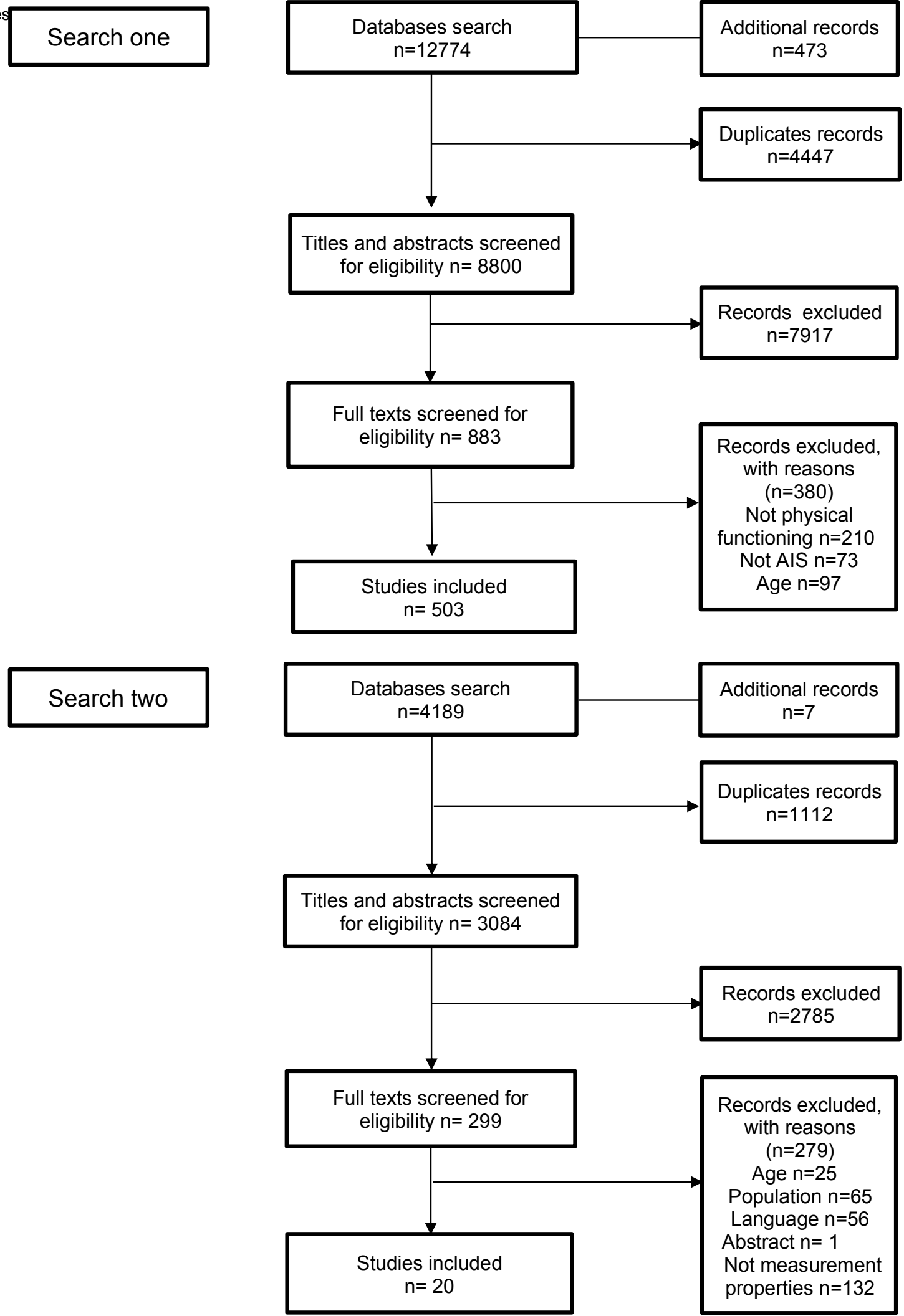
Construct validity	SRS-24 (Function)	2 hypotheses confirmed	+	High (One study very good quality
	SRS-22 (Activity)	2 out of 9 hypotheses confirmed	−	Moderate (Inconsistency)
	SRS-22r (Function)	4 hypotheses confirmed	+	Moderate (Inconsistency)
	SRS-30 (Function)	1 hypothesis confirmed	+	High (One study 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)

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,Modfied 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, ∝=Cronbach alpha, + = Sufficient,? = Indeterminate, − = Insufficient.

Figures legends

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

Figures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for eligibility n= 8800
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Full texts screened for
eligibility n= 883
Records excluded,
with reasons
(n=380)
Not physical
functioning n=210
Not AIS n=73
Age n=97
Studies included
n= 503
Search two
Databases search
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Additional records
n=7
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with reasons
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properties n=132
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n= 20

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Supplemental Data File 4 (doc.)

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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.