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REVIEW ARTICLE

Defining "successful" treatment outcomes in adolescent idiopathic scoliosis: a scoping review

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Abstract

Purpose Adolescent idiopathic scoliosis (AIS) is the most common type of scoliosis that affects children aged 10–18 years old, manifesting in a three-dimensional spinal deformity. This study aimed to explore outcome measures used in defining AIS treatment success. Particularly, analyzing the extent of qualitative and quantitative (radiographic and quality of life domains) measures to evaluate AIS and whether AIS treatment approaches (surgical, bracing and physiotherapy) influences outcomes used as proxies of treatment success.

Methods EMBASE and MEDLINE databases were used to conduct a systematic scoping review with 654 search queries. 158 papers met the inclusion criteria and were screened for data extraction. Extractable variables included: study characteristics, study participant characteristics, type of study, type of intervention approach and outcome measures.

Results All 158 studies measured quantitative outcomes. 61.38% of papers used radiographic outcomes whilst 38.62% of papers used quantitative quality of life outcomes to evaluate treatment success. Irrespective of treatment intervention utilized, the type of quantitative outcome measure recorded were similar in proportion. Moreover, of the radiographic outcome measures, the subcategory Cobb angle was predominantly used across all intervention approaches. For quantitative quality of life measures, questionnaires investigating multiple domains such as SRS were primarily used as proxies of AIS treatment success across all intervention approaches.

Conclusion This study identified that no articles employed qualitative measures of describing the psychosocial implications of AIS in defining treatment success. Although quantitative measures have merit in clinical diagnoses and management, there is increasing value in using qualitative methods such as thematic analysis in guiding clinicians to develop a biopsychosocial approach for patient care.

Keywords Adolescent idiopathic scoliosis · Success · Outcome measures · Treatment · Radiographic measures · Health-related quality of life

Introduction

Adolescent idiopathic scoliosis (AIS) is a three-dimensional spinal deformity involving sagittal, frontal and axial planes [1]. Mild AIS is defined as a lateral curvature (Cobb angle) greater than 10° with vertebral rotation in the absence of congenital or neuromuscular abnormalities. It is the most common spinal deformity affecting 1–3% of the pediatric population [2], with peak prevalence in 1.2% of females aged 12 [3]. The incidence of AIS is equal amongst females and males, but females have a tenfold increased likelihood of disease progression to a Cobb angle exceeding 30° [2]. The extent of curve progression reflects major periods of growth spurts and pubertal changes [4]. Exact etiology of AIS remains undefined, but it is believed to be a multifactorial, polygenic disorder [5].

Mild to moderate AIS is often asymptomatic; however, due to apparent visual deformities, it can induce significant emotional distress for some patients. Thus, the aim of treatment is to reverse or halt progression of curvature and improve quality of life. Current treatment options are split

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based on curve severity: conservative options (bracing or scoliosis-specific physical therapy) for mild to moderate AIS, whilst more invasive surgery is reserved for severe AIS.

Presently, there is a substantial body of evidence evaluating AIS treatment outcomes through quantitative radiographic and quality of life scales. However, to date, the literature lacks an approach that collates these various measures to appreciate the complexity of AIS and its biopsychosocial impacts on patients. Biopsychosocial impacts refer to the interplay between physical, psychological and social outcomes that are affected by AIS.

The aim of this review is three-fold:

1. Gather and examine, in a single review, the variety of outcome measures employed to determine AIS treatment success.
2. Explore whether different schools of treatments (surgical, bracing, physiotherapy etc.) employ different means of measuring successful treatment.
3. Investigate the extent to which quantitative or qualitative measurements for radiographic and quality of life domains are used in defining treatment success.

This scoping review is not intended to discredit the validity or accuracy of either radiographic or quantitative quality of life means to measure AIS treatment success. Rather, this study aims to synthesize a knowledge of current outcome measures used in defining treatment success and thus identify potential gaps in the holistic evaluation of a patient's treatment outcome.

Methods

Protocol design

In conducting this scoping review, we followed the preferred reporting items for systematic reviews and meta-analysis extension for scoping reviews (PRISMA-ScR) checklist [6].

Search strategy

A comprehensive literature search was performed using the bibliographic databases MEDLINE and EMBASE. The literature search was last updated on April 27th, 2022. All records were imported into Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia) for primary screening and data extraction.

Exclusion/inclusion criteria and article selection

Title and abstracts were individually screened by two independent reviewers (IJ and ST), with disagreements resolved through consultation between the two reviewers. For primary abstract and title screening, articles were excluded if one or more of the following criteria were met: (1) non-English primary literature; (2) not peer-reviewed; (3) systematic review or meta-analysis; (4) population of study below 7 years of age; (5) study participants diagnosed with functional scoliosis, de novo scoliosis or secondary scoliosis; (6) full text not available; (7) pilot study; (8) conference abstract; (9) no treatment/intervention investigated in study (Fig. 1).

The remaining articles were subsequently subjected to full-text screening conducted by two-independent reviewers (IJ and ST); any disagreements were resolved through consultation. Studies that contained the following criteria were used to determine eligibility of the full-text articles: (1) primary literature; (2) involved a treatment/intervention (surgical, bracing, physiotherapy, etc.), with a specific outcome (Cobb angle, SRS-22 etc.) measured; (3) study population limited to true AIS patients, not secondary scoliosis or other forms of spinal deformity; (4) presence of a defined intervention with direct effects on outcome measures (Fig. 1).

Data collection and extraction

Following full-text screening, data extraction was conducted for the screened articles. A comprehensive inventory spreadsheet was created to extract data. Extractable variables were jointly developed by all the authors, which included: study characteristics (author, year of publication, country, doi, type of study), study participant characteristics (age range, income levels, gender, place of residence and ethnic backgrounds of study participants), type of study (qualitative vs. quantitative vs. mixed methods research approach), type of intervention approach (e.g., surgical, bracing, physiotherapy), and outcome measurements (radiographic or health-related quality of life outcomes (HRQoL). Quantitative measures were defined as outcomes that had any numeric value or attribute. Qualitative measures in contrast were defined as outcomes without numeric values, but employed descriptive statements, themes or ideas of outcomes. Two reviewers (IJ and ST) independently extracted data, resolving any discrepancies through discussion (Fig. 1).

Results

Summative study characteristics and categorization

Of the studies analyzed in this scoping review, all 158 employed a quantitative research approach (Table 1). Geographically, research took place across 31 countries in total. Notably, 52 papers were conducted in the US, 18 in Japan, 13 in China, 10 in Turkey, 8 in Italy and 5 or less papers in each of the remaining 26 countries. The age range of

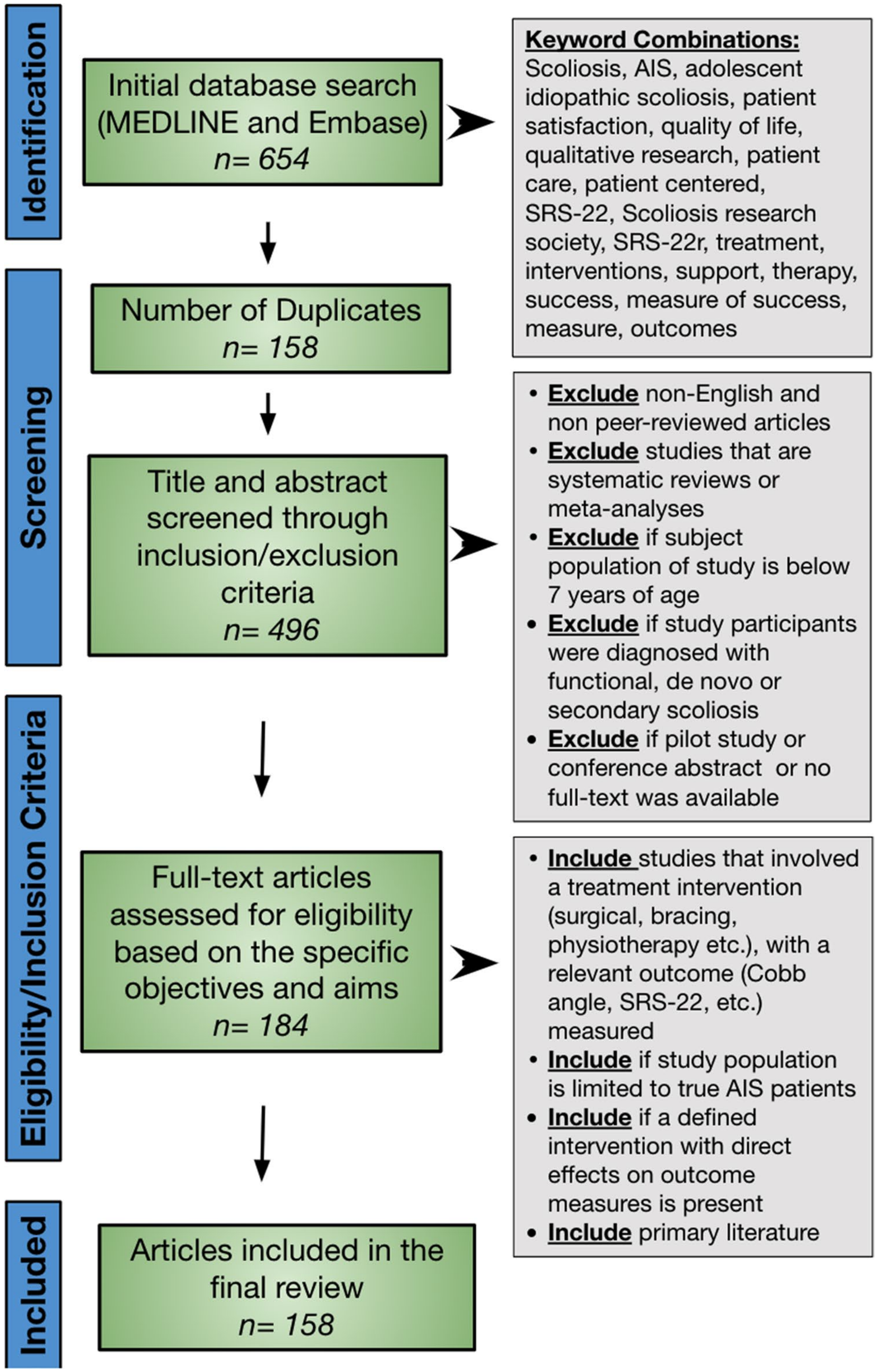

Fig. 1 Exclusion and inclusion criteria applied

participants at the time of study was stratified into 3 categories: (1) under 18 years of age, (2) over 18 years of age, and (3) included participants whose ages spanned across both categories. 97 papers included only participants under the age of 18, 11 papers had participants whose age ranges were greater than 18, and 47 papers included participants both below and above 18 years of age; 3 did not report age ranges of participants. With regards to gender, 141 papers included both male and female participants, whilst 11 papers only had female AIS participants included in their study. No papers looked at only male AIS participants and 6 papers did not specify the gender of the participants included in the

Table 1 Studies identified in the scoping review to determine outcome measured after treatment/intervention for adolescent idiopathic scoliosis

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Akazawa et al. [7] 2012 Japan	Quantitative	34–56	Both female and male	Japanese Not given Not given	Surgery	Not reported	SRS-22, Roland–Morris disability questionnaire (RDQ), pain grading scale (no pain, rare pain, occasional pain, frequent pain, constant pain), Moskowitz scale	Not reported
Altaf et al. [8] 2022 Australia	Quantitative	11–21	Both female and male	Australian Not given Not given	Surgery	Cobb angle	SRS-22	Not reported
Zhu et al. [9] 2017 China	Quantitative	14–18	Both female and male	Chinese Not given Not given	Surgery	Cobb angles, correction rate, flexibility, apical vertebral translation, apical vertebral rotation, coronal balance, sagittal vertical axis, thoracic kyphosis, lumbar lordosis, axial CT images	SRS-22	Not reported
Zhang and Sucato [10] 2019 US	Quantitative	13.8 +/− 1.9	Both female and male	Not Given Not given Not given	Surgery	Cobb angle, thoracic trunk shift, coronal balance, shoulder level, status of triradiate cartilage	SRS-30	Not reported
Aulisa et al. [11] 2015 Italy	Quantitative (no SRS-22)	11.62 +/− 1.1	Female	Italian Not given Not given	Bracing	Cobb angle	Not reported	Not reported
Babaee et al. [12] 2014 Iran	Quantitative	10–20	Both female and male	Not given Not given Not given	Bracing	Not reported	SRS-22	Not reported
Bailey et al. [13] 2021 Canada	Quantitative	10–20	Both female and male	Not given Not given Not given	Surgery	Not reported	Numerical rating scale (pain), state-trait anxiety inventory child form (STAIC), Pain catastrophizing scale-schild form (PCS-C), state-trait anxiety inventory-parent form (STAIP), pain catastrophizing scale-parent form (PCS-P), pediatric quality of life inventory-version 4 (PedsQL-4), functional disability index (FDI) SRS-30	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radio-graphic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Bastrom et al. [14] 2019 US	Quantitative	15 +/− 2	Both female and male	Not given Not given Not given	Surgery	Cobb angle, 3D kyphosis, thoracic rib prominence, trunk shift	SRS-24	Not reported
Bayrak et al. [15] 2021 Turkey	Quantitative	Not given	Both female and male	Not given Not given Not given	Bracing	Cobb angle, thoracic kyphosis angle, lumbar lordosis angle, tunk shift, shoulder asymmetry, body height difference	SRS-22	Not reported
Bennett et al. [16] 2013 US	Quantitative	14.6 +/− 2.1	Both female and male	Not given Not given Not given	Surgery	Thoracolumbar/lumbar Cobb Thoracic kyphosis Lumbar lordosis,coronal balance	SRS-22	Not reported
Bharucha et al. [17] 2013 US	Quantitative	10–21	Both female and male	Not given Not given Not given	Surgery	Thoracic Cobb angle, kyphosis and bending thoracic Cobb angle, cuve flexibility, thoracic angle of trunk rotation,	SRS-22	Not reported
Blondel et al. [18] 2012 France	Quantitative	14.7	Both female and male	Not given Not given Not given	Surgery	Coronal Cobb angle, thoracic kyphosis, lumbar lordosis	Not reported	Not reported
Brox et al. [19] 2012 Norway	Quantitative	13.2	Both female and male	Not given Not given Not given	Bracing	Cobb angle	SRS-22, global back disability question (overall rating of back disability), Oswestry disability index (evaluate back specific disability), general function score (disability in ADLs), EuoQol (generic questionnaire for HRQoL), EQ-5D (anxiety and depression), visual analogue score for assessment of overall current health (EQ-VAS)	Not reported
Carreon et al. [20] 2011 US	Quantitative	14.2 +/1.9	Both female and male	North America and Europe Not given Not given	Surgery	Cobb angle	SRS-22	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Chaib et al. [21] 2013 France	Quantitative	12–18	Both female and male	France Not given Not given	Surgery	Cobb angle	SRS-22	Not reported
Charalampidis et al. [22] 2018 Sweden	Quantitative	15.6	Both female and male	Sweden Not given Not given	Surgery	Cobb angle	SRS-22r, EQ-5D-3L index	Not reported
Chaudhary et al. [23] 2021 Nepal	Quantitative	12–18	Both female and male	Not given Not given Not given	Surgery	Cobb angle	SRS-30	Not reported
Cheung J. et al. [24] 2020 Hong Kong	Quantitative	12.6+/1.2	Both female and male	Not given Not given Not given	Bracing	Cobb Angle, major curve apex, convex and concave apical vertebral body heights were measured, and the apical ratio (convex height/concave height), flexibility	SRS-22r	Not reported
Cheung J. et al. [25] 2019 Hong Kong	Quantitative	12.53	Both female and male	Not given Not given Not given	Bracing	Cobb angle, supine flexibility, thoracic kyphosis,maximum thoracic kyphosis, lumbar lordosis, sagittal vertical axis, sacral slope, pelvic tilt, and pelvic incidence, truncal shift	SRS-22r	Not reported
Cheung P. et al. [26] 2019 Hong Kong	Quantitative	10–18	Both female and male	Chinese Not given Not given	Bracing	Coronal and sagittal Cobb angles, degree of apical vertebral rotation	SRS-22r, EQ-5D-3L index	Not reported
Christine et al. [27] 2008 Canada	Quantitative	12.8+/− 1.9	Both female and male	Not given Not given Not given	Bracing	Cobb angle	Not reported	Not reported
Coillard et al. [28] 2007 Canada	Quantitative	10–15	Both female and male	Not given Not given Not given	Bracing	Cobb angle	Not reported	Not reported
Colak et al. [29] 2017 Turkey	Quantitative	10–18	Both female and male	Not given Not given Not given	Physiotherapy OR physiotherapy & brace OR surgery	Cobb angle	SRS-23, walter reed visual assessment (deformity perception)	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Danielsson and Nachemson [30] 2001 Sweden	Quantitative	40	Female	Swedish Not given Not given	Surgery OR brace	Cobb method	SRS, MODEM's questionnaire (childbearing and sexual life), feeling of subjective back stiffness via visual analog scale, occurrence of medical problems, birth year of child, back pain, pregnancy complications, birth weight of the child	Not reported
de Bodman et al. [31] 2017 Switzerland	Quantitative	15	Both female and male	Not given Not given Not given	Surgery	Cobb angle		Not reported
Delfino et al. [32] 2017 Spain	Quantitative	Mean age for surgery 10–18 years, with f/up study ranging from 12–24 years	Both female and male	Not given Not given Not given	Surgery	Main ThL Cobb angle (ThLCobb), the secondary thoracic curve Cobb angle (TCobb), the curve flexibility determined by supine side-bending films (bending), the apical vertebral rotation (AVR) measured with the Perdriolle method, the lowest instrumented vertebra tilt angle (LIVtilt), and the coronal balance (C7 plumb line)	SRS-22, Oswestry disability index	Not reported
Delorme et al. [33] 1999 Canada	Quantitative	11–21	Both female and male	Not given Not given Not given	Surgery	Frontal Cobb angle, sagittal Cobb angle, maximum Cobb angle, correction of orientation of plane of maximum deformity	Not reported	Not reported
Diab et al. [34] 2010 US	Quantitative	8–18	Both female and male	White > African Americam > Hispanic > Asian American > Native American Not given Not given	Bracing	Cobb angle	SRS-30, SAQ	Not reported
Djurasovic et al. [35] 2018 US	Quantitative	8–18	Both female and male	Not given Not given Not given	Surgery	Not reported	SRS-22r	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Dufvenberg et al. [36] 2021 Sweden	Quantitative	9–17	Both female and male	Not given Not given Not given	Physical activity & brace OR scoliosis specific exercise R physical activity only	Cobb angle, angle of trunk rotation	SRS-22r, pictorial spinal appearance questionnaire, EV-VAS general, EQ-5D-Y dimensions, patient adherence, motivation and capability in performing intervention	Not reported
Duramaz et al. [37] 2020 Turkey	Quantitative	12–18	Both female and male	Not given Not given Not given	Surgery	Thoracic, thoracolumbar and lumbar Cobb angles	SRS-22, Oswestry disability index	Not reported
Enercan et al. [38] 2015 Turkey	Quantitative	21–30	Both female and male	Not given Not given Not given	Surgery	Thoracic curve, thoracolumbar/lumbar curve, Apical vertebral translation (main thoracic, thoracolumbar/lumbar), thoracic kyphosis, lumbar lordosis	SRS-22r, Oswestry disability index, back and leg pain numerical rating scale	Not reported
Ersen et al. [39] 2016 Turkey	Quantitative	10–15	Both female and male	Not given Not given Not given	Bracing	Cobb angle, height, TI-Coccyx distance, gibsoity	SRS-22	Not reported
Faldini et al. [40] 2021 Italy	Quantitative	41–63	Both female and male	Not given Not given Not given	Surgery	Coronal Cobb's angle of each curve, Coronal flexibility, angle of the main coronal curve between the pre-operative full-length standing and lateral supine side-bending X-rays, thoracic kyphosis and lumbar lordosis angles	Not reported	Not reported
Fletcher et al. [41] 2021 US	Quantitative	10–21	Both female and male	Not given US and Canada Not given	Surgery	Cobb angles	Visual analogue pain scale (VAS), quality of recovery score (QOR-9), number of days of school missed by the patient, work missed by any working parents who served as primary caregivers	Not reported
Floman et al. [42] 2015 Israel	Quantitative	13–16	Female	Not given Not given Not given	Surgery	Cobb angles	Not reported	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Floman et al. [43] 2020 Israel	Quantitative	13–17	Both female and male	Not given Not given Not given	Surgery	Cobb angle, Lordosis and Kyphosis angle, Bending radiograph angle	SRS-22, numerical questionnaire with scores ranging from 1–5 (regarding satisfaction with procedure, would they choose it again, and would they recommend it to a friend)	Not reported
Gammon et al. [44] 2010 US	Quantitative	11–17	Both female and male	Not given Not given Not given	Bracing	Cobb angle	SRS-22	Not reported
Gao et al. [45] 2021 China	Quantitative	10–17	Both female and male	Not given Not given Not given	Physiotherapy	Cobb angle, Coronal vertical axis, sagittal vertical axis, lumbar lordosis, thoracic kyphosis, thoracolumbar kyphosis, coracoid height difference, clavicular angle and T1 tilt	SRS-22, visual analog scale (VAS) score for back pain	Not reported
Ghandehari et al. [46] 2015 Iran	Quantitative	Not given	Both female and male	Not given Not given Not given	Surgery	Cobb angle, coronal balance	SRS-30	Not reported
Gornitzky et al. [47] 2016 US	Quantitative	15 +/− 2.3	Both female and male	Not given Not given Not given	Surgery	Not reported	Mean daily pain scores (1–10 self-reported scale), total opioid consumption	Not reported
Grabala and Helenius [48] 2020 Poland	Quantitative	14.8 +/− 2	Both female and male	Not given Not given Not given	Surgery	Cobb angle, spinal height, apical vertebral translation, thoracic kyphosis angle	SRS-22	Not reported
Gu et al. [49] 2022 China	Quantitative	14.8 +/− 2.6	Both female and male	Not given Not given Not given	Surgery	Cobb angle of thoracic and thoracolumbar curves, thoracic kyphosis, global coronal balance by the clavicle angle, apical vertebral column rotation angle	SRS-22, SF-36	Not reported
Guo et al. [50] 2014 China	Quantitative	10–14	Female	Not given Not given Not given	Bracing	Cobb angle	SRS-22	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Guy et al. [51] 2021 Canada	Quantitative	10–16		Not given Not given Not given	Bracing	Cobb angle (Main thoracic, thoracolumbar/lumbar), thoracic kyphosis, lumbar lordosis, vertebral axial rotation, apical rotation	SRS-22r	Not reported
Hamzaoglu et al. [52] 2013 Turkey	Quantitative	13–19	Both female and male	Not given Not given Not given	Surgery	Cobb angle for main thoracic curve, thoracolumbar/lumbar curve, kyphosis, lordosis, central sacral vertebral line, lower instrumented vertebral tilt and disc wedge	SRS-22, Global outcome score (GOS) for improvement or deterioration	Not reported
Helenius et al. [53] 2008 Finland	Quantitative	11–24	Both female and male	Not given Not given Not given	Surgery	Cobb angle (thoracic and lumbar, thoracic kyphosis and lumbar lordosis)	SRS-24, SF-36	Not reported
Hurford et al. [54] 2006 US	Quantitative	12–21	Both female and male	Not given Not given Not given	Surgery	Majo Cobb, apical vertebra translation, lowest instrumented vertebral translation, lowest instrumented vertebral tilt, disc angulation, coronal plumb	Combination of SRS-15, SRS-24, SRS-29, SRS-30	Not reported
Imagama et al. [55] 2016 Japan	Quantitative	12-–23	Both female and male	Not given Not given Not given	Surgery	Cobb angle, thoracic kyphosis, coronal/sagittal alignment, clavicle angle, radiographic shoulder height	SRS-22	Not reported
Izatt et al. [56] 2010 Australia	Quantitative	16.1	Both female and male	Not given Not given Not given	Surgery	Cobb angle (major), Instrumented curve Cobb angle, distal compensatory curve Cobb angle, T5-T12 kyphosis, Rib hump, shoulder, coronal spinal balance, sagittal spinal balance	SRS-24	Not reported
Janicki et al. [57] 2007 US	Quantitative	Providence group (11–15), TLSO group (10–17)	Both female and male	Not given Not given Not given	Surgery	Cobb angle progression	Not reported	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Jeans et al. [58] 2017 US	Quantitative	11–19	Both female and male	Not given Not given Not given	Surgery	Cobb angle, kyphosis angle	Not reported	Not reported
Karakaya et al. [59] 2012 Turkey	Quantitative	10–14	Both female and male	Not given Not given Not given	Surgery	Not reported	SRS-22	Not reported
Ketenci et al. [60] 2016 Turkey	Quantitative	12–20	Both female and male	Not given Not given Not given	Surgery	Coronal Cobb angle, sagittal Cobb angle, apical vertebral rotation	SRS-22, SAQ	Not reported
Koch et al. [61] 2001 US	Quantitative	12–17	Both female and male	Not given Not given Not given	Surgery	Cobb angle, head shift over pelvis, rib cage shift and rib cage rotation	OFFER (129 standardized self report instrument to evaluate body satisfaction and self image) and MBSRQ (69 item self report inventory measuring satisfaction with physical appearance, health and fitness)	Not reported
Koller et al. [62] 2021 Germany	Quantitative	16	Both female and male	Not given Not given Not given	Surgery	Lumbar curve (angle, bending degree, flexibility, correction %, SCI) Thoracic curve (angle, bending, flexibility, correction, SCI), lowest instrumental vertebrae, L3 tilt, L4 tilt, thoracic kyphosis, lumbar lordosis	SRS-22	Not reported
Kuklo et al. [63] 2002 US	Quantitative	10–19	Both female and male	Not given Not given Not given	Surgery	T1 tilt, clavicle angle, proximal thoracic side bending Cobb angle, Coracoid height, trapezius length, first rib-clavicle height	Post operative patient questionnaire (5 multiple choice questions with statements regarding shoulder balance and overall appearance)	Not reported
Kuroki et al. [64] 2015 Japan	Quantitative	10–14	Both female and male	Not given Not given Not given	Bracing	Initial brace correction rate, hanging correction rate	Not reported	Not reported
Kwan K. et al. [65] 2017 Hong Kong	quantitative	12 +/− 1.25	Both female and male	Not given Not given Not given	Physiotherapy **&** bracing	Cobb angle, truncal shift and angle of trunk rotation	SRS-22	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Kwan K. et al. [66] 2021 Hong Kong	Quantitative	10–15	Both female and male	Not given Not given Not given	Bracing	Cobb angle, supine flexibility, kyphosis and lordosis curves, upper/lower intervertebral axial rotation, torsion index, apical vertebral rotation	SRS-22	Not reported
Kwan M. and Chan [67] 2017 Malaysia	Quantitative	14.9 +/2.1 (Single surgeon) 15.8 +/− 5.7 (dual surgeon)	Both female and male	Not given Not given Not given	Surgery	Not reported	Not reported	Not reported
LaMontagne et al. [68] 2004 US	Quantitative -interview	11–18	Both female and male	Caucasian > African American (Scoliosis is more common in Caucasian than other ethnic groups) Not given Not given	Surgery	Not reported	Coping: avoidant = 1 to vigilant = 10 scale applied locus of control: series of 40 yes/no questions to determine internal/external locus of control. Lower scores = greater degree of internal locus of control. Activity outcomes (competence scales of youth self report and profile)	Not reported
Lansford et al. [69] 2013 US	Quantitative	14	Both female and male	Not given Not given Not given	Surgery	Thoracic Cobb angle	SRS-22, SRS-24	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Lark et al. [70] 2013 US	Quantitative	15 +/− 2	Both female and male	Not given Not given Not given	Surgery	Thoracic curve, thoracic flexibility, lumbar curve, lumbar flexibility, coronal C7 to CSVL, thoracic apical to C7 plumb, thoracic apical translation to CSVL, sagittal T5-12 and T10-L3, postoperative trunk motion (forward flexion, extension, right lateral flex, left lateral flex, right trunk rotation, left trunk rotation), trunk shape (shoulder height, coronal decompensation, thoracic rib prominence, lumbar prominence, trunk shift)	Not reported	Not reported
Larson et al. [71] 2014 US	Quantitative	10–21	Both female and male	Not given Not given Not given	Bracing OR surgery OR observation	Not reported	EuroQol5D (health status), SRS-22, spinal appearance questionnaire, oswestry disability index, orthopedic history, personal history (marital status, occupation), medical history (smoking, exposures, chest wall/breast reconstructive surgery)	Not reported
Larson et al. [72] 2019 US	Quantitative		Both female and male	Not given Not given Not given	Surgery	Percent curve flexibility, % Cobb correction, major Cobb angle, coronal balance, thoracic kyphosis, lumbar lordosis, sagittal balance	Spinal appearance questionnaire, SRS	Not reported
Li et al. [73] 2018 China	Quantitative	14.3 +/− 1.5	Both female and male	Not given Not given Not given	Surgery	Coronal Cobb angle	SRS-22	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Librianto et al. [74] 2022 Indonesia	Quantitative	time or surgery 19.6 +/− 4.28 and 21.7 +/4.79 (derotation and translation respectively)	Both female and male	Not given Not given Not given	Surgery	Not reported	SRS-22	Not reported
Lonner et al. [75] 2009 US	Quantitative	15	Both female and male	Not given Not given Not given	Surgery	Major curve correction, cephalad thoracic curve correction, caudad compensatory lumbar curve correction, ccoronal balancce, lumbar lordosis, sagittal abalance, tilt angle of most cuadad instrumented vertebra, thoracic kyphosis, angle of trunk rotation	SRS-22	Not reported
Lonner et al. [76] 2019 US	Quantitative	10–21	Both female and male	Not given Not given Not given	Surgery	Major Cobb angle, angle of trunk rotation thoracic/lumbar	Body image disturbance questionnaire—scoliosis version, SRS-22	Not reported
Lonner et al. [77] 2006 US	Quantitative	14.6 +/− 1.54 (thoracoscopic group) 14.3 +/− 2.46 (posterior fusion group)	Both female and male	Not given Not given Not given	Surgery	Magnitude of major curve, % correction at final follow up, coronal balance, tilt angle of most caudad instrumented vertebra, kyphosis	SRS-22	Not reported
Lonner et al. [78] 2019 US	Quantitative	23–70 yrs (average 43.7 +/− 15.8yrs) for adults, 11–19 (average 15.7 yrs) for adolescent	Both female and male	Not given Not given Not given	Surgery	Major Cobb angle, T5-T12 kyphosis, lumbar lordosis	SRS-22r	Not reported
Lonner et al. [79] 2009 US	Quantitative	11–18.4 years at time of Sx (PSF group) and 10.2–18.6 years at time of Sx (VATS group)	Both female and male	Not given Not given Not given	Surgery	Major Cobb angle, % curve correction, kyphosis curve, absolute change in kyphosis	SRS-22	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Lonner et al. [80] 2020 US	Quantitative	15 +/− 2	Both female and male	Not given Not given Not given	Surgery	Cobb angle, T2-T12 kyphosis, sagittal vertical axis, coronal imbalance, angle of trunk rotation, T2-T12 kyphosis, lumbar lordosis, surface rotation, lateral deviation, sagittal imbalance, pelvic obliquity, pelvic inclination and maximum vertebra rotation	SRS-22	Not reported
Lonstein [81] 2018 US	Quantitative	Average age at follow up 47.3 years (35.8–67.5) with average follow up of 327 years (20.4–59.1)	Both female and male	Not given Not given Not given	Surgery	Thoracic curve (bending, % correction), lumbar curve (bending, % correction), Thoracic kyphosis, lumbar lordosis, central sacral line	SRS-30, oswestry disability index	Not reported
Luo et al. [82] 2017 China	Quantitative	C group (14.5 +/2) I group (13.9 +/− 2.3) S group (14.8 +/− 2.3)	Both female and male	Not given Not given Not given	Surgery	Lumbar spine modifier, thoracic sagittal profile, Cobb levels of MT curve, Cobb angle of MT curve, Cobb angle of convex bending, vertebral rotation (Nash-Moe), apical vertebra translation, thoracic trunk shift, thoracic kyphosis and lumbar lordosis	simplified Chinese version of the SRS-22 questionnaire at preop and latest follow up	Not reported
Marciano et al. [83] 2021 US	Quantitative	15.1 +/− 2.1	Both female and male	Not given Not given Not given	Surgery	Upper thoracic curve, thoracic curve, lumbar curve, maximum kyphosis (degrees)	SRS-22	Not reported
Mariconda et al. [84] 2016 Italy	Quantitative	14.8 +/− 2.3 (11–22 years)	Both female and male	Not given Not given Not given	Surgery	Rib hump, trunk shift imbalance, thoracic Cobb angle, lumbar Cobb angle, thoracic kyphosis (degree)	SF-36, SRS-23	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Marks et al. [85] 2007 US	Quantitative	Age at surgery: males 16+/−2, female 14+/−2	Both female and male	Not given Not given Not given	Surgery	% correction of primary curve, % forrection to preoperative flexibility, loss of correction at 2 years postop, % correction of upper thoracic curve, change in kyphosis, lordosis, thoracic apical translation, thoracolumbar/lumbar apical translation	visual analog scale pain scores, SRS-22	Not reported
Matsumura et al. [86] 2021 Japan	Quantitative	13–28, (17)	Both female and male	Not given Not given Not given	Surgery	Thoracic kyphosis angle, C7-CSVL, Cobb angle, Thoracic apex—CSVL, Lumbar apical vertebral translation, thoracic curve, thoracolumbar/lumbar curve, lumbosacral curve, L4 and L5 tilt	SRS-22	Not reported
Mens et al. [87] 2022 Netherlands	Quantitative	14–17 (15)	Both female and male	Not given Not given Not given	Surgery	Not reported	SRS-22, oswestry disability index, EuroQol five-dimension-three level questionnaire, EuroQol Visual Analogue scale (EQ-VAS), back and leg pain intensity	Not reported
Merloa et al. [88] 2002 US	Quantitative	13–18 (14+/−2.3)	Both female and male	Not given Not given Not given	Surgery	Curve magnitude, magnitude of curve correction	SRS-24	Not reported
Mimura et al. [89] 2018 Japan	Quantitative	14.8+/−2 (12–20)	Both female and male	Not given Not given Not given	Surgery	Thoracic curve degree, correction rate %, angle of trunk rotation, ATR correction rate, maximum bend thoracic curve, flexibility, Apical vertebral translation	SRS-22	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Miyanji et al. [90] 2018 Canada	Quantitative	15.5 +/1.8 (Anterior spinal instrumentation and fusion) 15/3 +/2 (posterior spinal instrumentation and fusion)	Both female and male	Not given Not given Not given	Surgery	Coronal Cobb angles of thoracic and TL curves, sagittal Cobb angles of thoracic kyphosis, lumbar lordosis, TL junction, C7 plumb line, disc angle below the lowest instrumental vertebrae, TL/L curve flexibility, stable vertebrae	SRS-22	Not reported
Monticone et al. [91] 2014 Italy	Quantitative	12.5, 12.4	Both female and male	Not given Not given Not given	Task oriented exercise and active self correction	Cobb angle, angle of trunk rotation	SRS-22	Not reported
Moramarco et al. [92] 2016 US	Quantitative	13.89	Both female and male	Not given Not given Not given	Physiotherapy	Cobb angle, angle of trunk rotation	Not reported	Not reported
Morr et al. [93] 2015 US	Quantitative	12–16 (control group) 12–17 (skip group)	Both female and male	Not given Not given Not given	Surgery	Proximal thoracic Cobb angle, main thoracic Cobb angle, thoracolumbar/lumbar Cobb angle, regional thoracic kyphosis, T2-T5 RTK, T5-T12 RTK. T2-T12 RTK, thoracolumbar junction sagittal curvature at T10-L2, lumbar lordosis, apical vertebral body rib ratio, Apical rib spread difference	SRS-22	Not reported
Muller et al. [94] 2011 Germany	Quantitative	12.9 +/− 2.3		Not given Not given Not given	Bracing	Not reported	German version of SRS-22	Not reported
Nachemson and Peterson [95] 1995 Sweden	Quantitative	10 − 15 (12 years)	Female	Not given Not given Not given	Bracing	Apical vertebrae, Cobb angle, inmbalance, increase in height, rib hump, kyphosis Cobb angle, rotation	Not reported	Not reported
Negrini et al. [96] 2019 Italy	Quantitative	12	Both female and male	Not given Not given Not given	Physiotherapy	Maximum Cobb angle, ATR, hump height,	Not reported	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Newton et al. [97] 2013 US	Quantitative	14.5 +/− 2	Both female and male	Not given Not given Not given	Surgery	Shoulder height difference, trunk shift, thoracic rib prominence, lumbar prominence, trunk flexibility. lumbar coronal Cobb angles, coronal balance (C7–CSVL distance, where CSVL is Central Sacral Vertical Line)), sagittal thoracic kyphosis (T5–T12), and lumbar lordosis (T12–S1)	SRS-24	Not reported
Newton et al. [98] 2020 US	Quantitative	20.2–33.1 (25 +/− 2.3)	Both female and male	Not given Not given Not given	Surgery	Coronal Cobb angle (MT, TL/L), coronal balance, Central sacral vertical line, sagittal thoracic kyphosis, lumbar lordosis, sagittal vertical axis line	SRS-22	Not reported
Nohara et al. [99] 2015 Japan	Quantitative	11–22 (15.7 +/− 3.0) for PSF, 12–25 (15.5 +/− 3.7) ASF	Female	Not given Not given Not given	Surgery	Disc degeneration, Cobb angle, instability	SRS-30	Not reported
O'Donnell et al. [100] 2018 US	Quantitative	14.8 (ASF) 15.3 (PSF)	Both female and male	Not given Not given Not given	Surgery	Coronal and sagittal balance, thoracic trunk shift, thoracolumbar Cobb angle, lowest end vertebrae (LEV), lowest instrumented vertebrae (LIV), LIV tilt angle, and shoulder height difference	SRS-22r	Not reported
Okada et al. [101] 2013 Japan	Quantitative	11–22 (14.4 +/− 3.5) for Stainless steel, 10–24 (14.4 +/− 3.7) titanium	Both female and male	Not given Not given Not given	Surgery	Cobb angle of the main curve, correction rate, global coronal and sagittal balance, and thoracic kyphosis	SRS-22	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Okada et al. [102] 2015 Japan	Quantitative	10–29 (16.8 ± 4.7)	Both female and male	Not given Not given Not given	Surgery	Cobb angles of the main and thoracic curves, L4 tilt angle, correction rate, coronal and sagittal global balances, thoracic kyphosis (T5–T12), and lumbar lordosis (L1–S1),	SRS-22	Not reported
Okubo et al. [103] 2022 Japan	Quantitative	13–29 (16.4 +/− 3.1)	Both female and male	Not given Not given Not given	Surgery	Global spinal sagittal alignment, mean Cobb angle of main TL/L and minor thoracic curve, sagittal parameters (sagittal vertical axis, C2-7 SVA, C2-7 lordosis, T1 slope, thoracic kyphosis, T10-L2 kyphosis, lumbar lordosis, pelvic incidence, pelvic tilt, sacral slope)	SRS-22, oswestry disability index	Not reported
Pasquini et al. [104] 2016 Italy	Quantitative	13.15 +/− 1.7	Both female and male	Not given Not given Not given	Bracing	Cobb angle, curve progression, rib hump, spine balance, number of patients whose curve did not exceed 30 degree Cobb	Not reported	Not reported
Pehlivanoglu et al. [105] 2021 Turkey	Quantitative	9–15 (11.1; VBT), 9–15 (10.9, fusion)	Both female and male	Not given Not given Not given	Surgery	Trunk endurance, motor strength of trunk muscles, lumbar range of motion, lumbar bending flexibility, major curve magnitude, coronal balance, sagittal balance	SRS-22, SF-36	Not reported
Pellegrino and Avanzi [106] 2014 Brazil	Quantitative	15.6	Both female and male	Not given Not given Not given	Surgery	Cobb angle, major curve correction/degree, minor curve correction/degree	SF-36, SRS-30	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Pellios et al. [107] 2016 Greece	Quantitative	40.4 +/− 3.2	Female	Not given Not given Not given	Bracing	Rib hump asymmetry, shoulder and scapulae evaluation, forward bending for asymmetries of lateral contours, Cobb angle of major and minor curve	Oswestry disability index, SF-36	Not reported
Price et al. [108] 2003 US	Quantitative	Group A (16), B (15), C(14)	Both female and male	Not given Not given Not given	Surgery	Cobb angle	Not reported	Not reported
Qiu et al. [109] 2021 US	Quantitative	8–16	Both female and male	White > Other > Black Not given Not given	Surgery	Cobb angle thoracic curve, lumbar curve, kyphosis curve, lordosis curve, thoracic bend and lumbar bend	SRS-22	Not reported
Ramo et al. [110] 2019 US	Quantitative	14 +/− 2.2	Both female and male	Not given Not given Not given	Surgery	Magnitude and rate of change in Cobb angles over time,	Not reported	Not reported
Rao et al. [111] 2017 US	Quantitative	Protocol 1 (11–21) 2 (11–20) 3 (11–20)	Both female and male	Not given Not given Not given	Plan of care protocol post fusion	Not reported	Questionnaire on the comfort, care received, understanding of information, satisfaction and hospitalization experience satisfaction. pain scores, mobility	Not reported
Remes et al. [112] 2004 Finland	Quantitative	28	Both female and male	Not given Not given Not given	Surgery	Leg length discrepancy, degree of hump, waist asymmetry, straight leg-raising test (back pain), thoracic and lumbar Cobb angles, spinal balance, thoracic kyphosis, lumbar lordosis, spinal mobility, trunk strength (lumbar flex/extension, trunk side bend, arch up, squat, sit up)	SRS-22	Not reported
Riouallon et al. [113] 2016 France	Quantitative	Mean age at surgery 14.7 (11–21), mean follow up 21 (15–31)	Both female and male	Not given Not given Not given	Surgery	Cobb angle, coronal misalignment, lumbar lordosis, thoracic kyphosis, pelvic incidence, sacral tilt, sacral vertical axis	SRS-30	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Rivett et al. [114] 2009 South Africa	Quantitative	13–16	Both female and male	Not given Not given Not given	Bracing	Not reported	Brace questionnaire (34 questions in 8 domains: general health perception, physical functioning, emotional functioning, self esteem and aesthetics, vitality, school activity, bodily pain and social functioning)	Not reported
Roberts et al. [115] 2014 UK	Quantitative	13–23 (16.7)	Both female and male	Not given Not given Not given	Surgery	Size of thoracolumbar/lumbar curve, thoracic and lumbar apical vertebrae translation, Cobb angle on lumbar convex bending, size of compensatory thoracic curve, trunk shift, thoracic kyphosis, lumbar lordosis, global sagittal balance, thoracic and lumbar flexibility, rates of correction of curve	SRS-22	Not reported
Rushton et al. [116] 2021 Canada	Quantitative	IOT (15.2 +/− 1.8) Non-IOT (15.2 +/− 1.7)	Both female and male	Not given Not given Not given	Surgery	PT Cobb, PT flexibility, MT Cobb, MT flexibility, MT C-DAR, thoracic AVT, lumbar Cobb, lumbar AVT, kyphosis, lumbosacral lordosis, rib hump, rib hump correction, lumbar prominence and lumbar prominence correction	SRS-22	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Rushton et al. [117] 2015 UK	Quantitative	15 years 10 months, 15 years 5 months	Both female and male	Not given Not given Not given	Surgery	Rib hump, main thoracic curve (Cobb, % correction), lumbar curve, thoracic kyphosis, lumbosacral lordosis	Modified scoliosis research society outcome instrument (MSRSI) completed preop. it is the developed SRS24 contains 23 questions on 4 domains: pain, self image, activity/function, mental health and satisfaction (measured post-op only)	Not reported
Sakai et al. [118] 2021 Japan	Quantitative	14.1 +/− 2.4	Both female and male	Not given Not given Not given	Surgery	Main thoracic Cobb angle, active bending degree, flexibility, thoracic kyphosis, lumbar lordosis, apical vertebral rotation, rib hump, correction rate	SRS-22r	Not reported
Sakai et al. [119] 2019 Japan	Quantitative	10–19	Female	Japanese Urban Not given	Surgery	Coronal main Cobb angle, sagittal thoracic kyphosis angle, lumbar lordosis angle, apical vertebral rotation, rib hump size, cincinnati correction index	Scoliosis Japanese questionnaire-27, Japanese version of the 12-time short-form health survey and SRS-22r	Not reported
Sanders et al. [120] 2010 US	Quantitative	14.41	Not given	Not given Not given Not given	Surgery	Not reported	SRS-30	Not reported
Scaramuzzo et al. [121] 2017 Italy	Quantitative	14.8 +/− 2.3	Both female and male	Not given Not given Not given	Surgery	Coronal curve Cobb angle, Apical vertebral rotation, apical vertebral translation, sagittal curve Cobb angle	SRS-22	Not reported
Schreiber et al. [122] 2019 Canada	Quantitative	10–18	Not given	Not given Not given Not given	Physiotherapy (Schroth exercises)	Cobb angle	Global rating of change (GRC)	Not reported
Schreiber et al. [123] 2015 Canada	Quantitative	10–18	Both female and male	Not given Not given Not given	Physiotherapy (Schroth exercises)	Not reported	SRS-22r, Spinal appearance questionnaire	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Segal et al. [124] 2020 US	Quantitative	14.55 (mean)	Both female and male	Not given Not given Not given	Surgery	Main thoracic curve magnitude, lumbar curve magnitude, thoracic apical translation to central sacral vertical line, thoracic kyphosis, lumbar lordosis, distal junctional kyphosis, truncal flexibility	SRS-22	Not reported
Segreto et al. [125] 2019 US	Quantitative	10–25	Both female and male	Sports: (Black > Hispanic > White > Asian > Other), No-sports: (Black > Hispanic > White > Other > Asian) Not given Not given	Non contact sport participation	Main Cobb curve, secondary Cobb curve, tertiary, C7PL, thoracic kyphosis, pelvic tilt, pelvic incidence minus lumbar lordosis, sagittal vertical axis	SRS-30, body image disturbance questionnaire (BIDQ), spinal appearance questionnaire (SAQ) and AIS screening questionnaire	Not reported
Senkoylu et al. [126] 2020 Turkey	Quantitative	14.6 +/− 2.5	Both female and male	Not given Not given Not given	Surgery	Cobb angle of main and accompanying curves, correction rate and flexibility of curves	SRS-22	Not reported
Shen et al. [127] 2017 China	Quantitative	Low density group —14.2 +/− 2.4, High density group —14.8 +/− 1.9	Both female and male	Not given Not given Not given	Surgery	Vertebral rotation index, convex-bending Cobb angle, curve flexibility, lumbar spine modifier, thoracic sagittal profile, MT Cobb angle, thoracic kyphosis, lumbar lordosis, proximal junctional kyphosis, apical vertebral translation, thoracic trunk shift	SRS-22	Not reported
Sieberg et al. [128] 2013 US	Quantitative	8–21	Both female and male	White > Black/African American > Asian/Asian American > Hispanic > Other Not given Not given	Surgery	Not reported	SRS-30, number of missed days of work/school due to back pain, use of medication	Not reported
Simony et al. [129] 2019 Denmark	Quantitative	Baseline Cobb 20–29 —13.15 +/− 0.99, 30–39 —13.38 +/− 1.21, 40–45 —13.54 +/− 1.45	Both female and male	Not given Not given Not given	Bracing	Cobb angle	Not reported	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Simony et al. [130] 2015 Denmark	Quantitative	Age at treatment 12–18 (14.3; surgery) age at follow up 33–47 (37.6; surgery) | age at treatment 14–19 (15.8; Boston Brace), age at follow up 34–47 (41.4; Boston Brace)	Both female and male	Not given Not given Not given	Brace OR posterior spinal fusion	Mean Cobb angle of major curve, kyphosis and lordosis, proximal segment degeneration, proximal junctional kyphosis, distal segment degeneration, L5-S1 noncontiguous fusion	Not reported	Not reported
Singla et al. [131] 2014 US	Quantitative	14.2 +/− 2.2	Both female and male	Not given Not given Not given	Surgery	Cobb angles, kyphosis, lumbar lordosis, coronal balance, sagittal balance, thoracic and lumbar apical vertebral translation, trunk shift, thoracic and lumbar rib prominences	SRS-22	Not reported
Smith et al. [132] 2006 Canada	Quantitative	12.4–20.7 (16.4)	Both female and male	Not given Not given Not given	Surgery	Cobb angle, rib prominence, lateral balance, frontal balance, shift of apex from central sacral line, shoulder level, pelvic balance	Parent's and patient's independent ratings of shoulder blades, shoulders, waist and overall appearance + quality of life profile for spinal disorders	Not reported
Smucny et al. [133] 2011 US	Quantitative	Hybrid 14.4 +/2.1, screw 14.1 +/1.9	Both female and male	Not given Not given Not given	Surgery	Not reported	SRS-30, spinal appearance questionnaires (SAQ)	Not reported
Sudo et al. [134] 2014 Japan	Quantitative	10–20	Both female and male	Not given Not given Not given	Surgery	Proximal thoracic curve, main thoracic curve, thoracolumbar/lumbar curve, thoracic kyphosis, thoracolumbar kyphosis, lumbar lordosis, balance parameters and translational data, vertebral rotation angle of thoracic apical vertebra	SRS-22	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Sudo et al. [135] 2013 Japan	Quantitative	12–23	Both female and male	Not given Not given Not given	Surgery	Thoracolumbar/lumbar curve, thoracic curve, main-curve kyphosis, instrumented-level kyphosis, thoracic kyphosis, lumbar lordosis, balance parameters and translational and rotational data	SRS-30	Not reported
Sundar et al. [136] 2022 US	Quantitative	10–18	Both female and male	Not given Not given Not given	Surgery	Not reported	Not reported	Not reported
Takahata et al. [137] 2007 Japan	Quantitative	12–20	Both female and male	Not given Not given Not given	Surgery	Major curve Cobb angle, apical vertebral translation, thoracic kyphosis, lumbar lordosis	SRS-24	Not reported
Tanaka et al. [138] 2021 Japan	Quantitative	Conventional technique —15.8 +/− 1.8, Navigation Technique —17.8 +/− 3.9	Both female and male	Not given Not given Not given	Surgery	Thoracolumbar/lumbar Cobb angle, percent correction, number of fused vertebrae	SRS-22	Not reported
Theologis et al. [139] 2015 US	Quantitative	14.7 +/− 1.7 (10–18)	Both female and male	Not given Not given Not given	Surgery	Not reported	SRS-30	Not reported
Tsirikos et al. [140] 2017 UK	Quantitative	11–23.3	Both female and male	Not given Not given Not given	Surgery	Cobb angle, upper thoracic, main thoracic, lumbar, thoracic kyphosis, lumbar lordosis, coronal imbalance (trunk shift), sagittal imbalance	SRS-22	Not reported
Tsutsui et al. [141] 2009 US	Quantitative	9–23	Both female and male	Not given Not given Not given	Surgery	Not reported	SRS-24	Not reported
Uehara et al. [142] 2020 Japan	Quantitative	12–19	Both female and male	Not given Not given Not given	Surgery	Cobb angle and thoracic kyphosis from T5 to T12, clavicular angle, distance from C7 plumb line to the central sacral vertical line, LIV tilt	Japanese orthopedic association back pain evaluation questionnaire, visual analog scale (VAS) for low back pain SRS-22r	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Uehara et al. [143] 2018 Japan	Quantitative	12–20 (14.7 +/− 2.1)	Both female and male	Not given Not given Not given	Surgery	Cobb angle of the upper thoracic curve, correction rate of the Cobb angle, Cobb angle of the main thoracic curve, Cobb angle of the thoracolumbar/lumbar curve, apical trunk rotation, thoracic kyphotic angle, lumbar lordotic angle, apical translation, clavicular angle, C7 plumb line	SRS-22r	Not reported
Ugwonaliet al. [144] 2004 US	Quantitative	10–18	Both female and male	White > Other Not given average income: no treatment –$114,650, Braced –$103,772	Bracing	Cobb angle	Child health questionnaire, pediatric outcomes data collection instrument (CHQ PF-28) given to the parents of patients with AIS	Not reported
Urquhart et al. [145] 2014 UK	Quantitative	11.8–15	Both female and male	Not given Not given Not given	Surgery	Cobb angle	SRS-22, Patient satisfaction via visual analogue scale (VAS)	Not reported
Verma et al. [146] 2010 US	Quantitative	11.6–21.6	Both female and male	Not given Not given Not given	Surgery	Cobb angle of thoracolumbar/lumbar curve, mean thoracic curve, thoracic kyphosis, proximal junctional kyphosis, distal junctional kyphosis, lumbar lordosis, instrumented segmental lordosis and instrumented segmental coronal, disc wedge, end instrumented tilt, sagittal balance, apical trunk rotation	SRS-22	Not reported
Violas et al. [147] 2019 France	Quantitative	12–18	Both female and male	Not given Not given Not given	Surgery	Cobb angle, thoracic kyphosis, lumbar lordosis, Apical vertebra rotation	Not reported	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Wang et al. [148] 2008 China	Quantitative	11–18	Both female and male	Not given Not given Not given	Surgery	Coronal Cobb, sagittal kyphosis, sagittal lordosis, apical vertebral rotation, apical vertebral translation, Trunk shift,	Not reported	Not reported
Watanabe et al. [149] 2022 Japan	Quantitative	13–25	Both female and male	Not given Not given Not given	Surgery	Cobb angles of proximal thoracic, main thoracic, thoracolumbar/lumbar curves, apical vertebral translation, T1 tilt angle, clavicle angle, radiographic shoulder height, thoracic kyphosis, thoracolumbar kyphosis, lumbar lordosis	SRS-22	Not reported
Wei et al. [150] 2017 China	Quantitative	14.7 +/− 1.7	Both female and male	Not given Not given Not given	Surgery	Cobb angles of proximal thoracic, main thoracic and thoracolumbar/lumbar curves, coronal balance, radiographic shoulder height, apical vertebral rotation, apical vertebral translation	SRS-22	Not reported
White et al. [151] 1999 US	Quantitative	10–20	Both female and male	White > Black > Hispanic > Undetermined Not given Not given	Surgery	Cobb angle	SRS-24	Not reported
Wibmer et al. [152] 2019 Austria	Quantitative	9.5–15.2	Both female and male	Not given Not given Not given	Bracing & physiotherapy	Cobb angle	SRS-24, satisfaction with treatment,	Not reported
Won et al. [153] 2021 Korea	Quantitative	Experimental group −14.5 +/− 2.5, control group −15.9 +/− 2.69	Female	Not given Not given Not given	Neuromuscular stabilization technique and home exercise program	Cobb angle	Not reported	Not reported
Yang J. et al. [154] 2021 Korea	Quantitative	15–35.3	Female	Not given Not given Not given	Surgery	Hump height, hump angle, Cobb angle	SRS-22, trunk appearance perception scale (TAPS)	Not reported
Yang J. et al. [155] 2013 Korea	Quantitative	Conventional open −14 +/− 1.5, MISS −15 +/− 1.9	Not given	Not given Not given Not given	Surgery	Cobb angle, coronal balance, spinal vertical axis, thoracic kyphosis, lumbar lordosis	SRS-22	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Yang J. et al. [156] 2021 Korea	Quantitative	12–18	Female	Not given Not given Not given	Surgery	Cobb's angle, coronal balance, clavicular angle, sagittal vertical axis, thoracic kyphosis angle, lumbar lordosis angle	SRS-22	Not reported
Yang M. et al. [157] 2015 China	Quantitative	Group A −12.52 +/− 1.45, Group B −12.11 +/− 1.42	Both female and male	Not given Not given Not given	Surgery	Cobb angle, coronal balance, sagittal vertical axis, thoracic kyphosis, lumbar lordosis	Not reported	Not reported
Yeh et al. [158] 2016 Taiwan	Quantitative	10–19	Both female and male	Not given Not given Not given	Surgery	Cobb angle, thoracic kyphosis, lumbar lordosis	Not reported	Not reported
Yong et al. [159] 2013 Australia	Quantitative	10.8–22.4	Female	Not given Not given Not given	Surgery	Cobb angle of major curve, Cobb angle of the instrumented levels, Cobb angle of the compensatory lumbar curve, Cobb angle of the T5-T12 kyphosis, coronal spinal balance, T1 tilt angle and shoulder balance	SRS-24	Not reported
Zacharia et al. [160] 2018 India	Quantitative	11–17	Both female and male	Not given Not given Not given	Surgery	Cobb angle	SRS-30	Not reported
Zheng et al. [161] 2017 China	Quantitative	12–18	Both female and male	Not given Not given Not given	Surgery	Cobb angle, translation of the apical vertebra, Cobb angle correction ratio, thoracic kyphosis, rib hump	Simplified Chinese (mainland) version of SRS-22 questionnaire	Not reported
Zhuang et al. [162] 2021 China	Quantitative	10.9–19	Both female and male	Not given Not given Not given	Surgery	Thoracolumbar/lumbar Cobb angle, thoracic kyphosis, thoracolumbar kyphosis, lumbar lordosis, sagittal vertical axis, lowest instrumented vertebra (LIV) translation, tilt, rotation and other related parameters	SRS-22	Not reported
Negrini et al. [163] 2008 Italy	Quantitative	13.2 +/− 1.8	Both female and male	Not given Not given Not given	Physiotherapy or bracing or exercises	Cobb angle (thoracic proximal, thoracic, thoraco-lumbar, lumbar)	Not reported	Not reported

Table 1 (continued)

Author, year, and country	Study design	Age	Gender	Participant ethnic background, place of residence and income level	Type of intervention approach	Quantitative radiographic outcomes	Quantitative quality of life outcomes	Qualitative outcomes
Luaks et al. [164] 2021 US	Quantitative	10–18	Both female and male	Not given Not given Not given	Bracing	Cobb angle, Risser grade, RVAD, kyphosis, lordosis	Not reported	Not reported

study. No papers specified the place of residence of subjects (rural or urban), nor their income level. Ethnic background of participants was specified in 16 papers.

Study outcome measures

Outcome measures from all 158 papers were broadly categorized into radiographic or health related quality of life (HRQoL) outcomes. Radiographic measures were then subcategorized into "Cobb angle", "trunk shape/alignment" and "flexibility/movement". HRQoL measures were subcategorized into the following: "questionnaires investigating multiple domains", "disability specific questionnaires", "visual appearance specific questionnaires", "pain specific questionnaires", and "mental health specific questionnaires". The subcategory of "questionnaires investigating multiple domains" refers to measures that assess multiple domains of outcomes (e.g., scoliosis research society (SRS), Short form survey (SF-36), Global rating of change (GRC), quality of recovery score (QOR-9), EuroQol-5 dimension (EQ-5D), bracing questionnaires).

Amongst the studies selected for the scoping review, radiographic outcomes were reported a total of 275 (61.38%) times whilst quantitative HRQoL measurements were reported 173 (38.62%) times, as measures to evaluate intervention success. No papers reported qualitative HRQoL measurements (Table 2).

Intervention Type and Specific outcome measure subcategories

Interventions described in the 158 papers were categorized into 4 broad treatments: (1) surgery, (2) bracing, (3) physiotherapy or physical activity, and (4) a combination of physiotherapy and bracing. A combination of surgery with other treatment interventions was not present in any of the papers. Amongst papers that explored surgical intervention in AIS patients, 50.48% of treatment outcomes were measured by radiographic means, whilst 49.52% were measured by HRQoL. For studies investigating bracing as an intervention, 57.14% of treatment outcomes were measured by radiographic means whilst 42.86% by HRQoL. Moreover, for physiotherapy or physical activity, radiographic measures accounted for 58.82% of outcomes whilst HRQoL measures accounted for 41.18% of outcomes. While only 12 interventions used a combination of physiotherapy and bracing, 50% of treatment outcomes were measured by radiographic means, and the remaining 50% by HRQoL. Note that if both radiographic and HRQoL measures were used in the same study, a tally was given to each category (Table 3).

An analysis of intervention versus specific radiographic outcome subcategories was also conducted. "Cobb angle" was the most investigated subcategory of radiographic outcomes

Table 2 Outcome measures investigated across 158 papers included in the review

		Subcategory	Total tally	Subcategory percentage (%)	Outcome percentage (%)
Quantitative Outcome	Radiographic	Cobb angle[1]	142	51.64	61.38
		Trunk shape/alignment[2]	64	23.27	
		Flexibility/movement[3]	69	25.09	
		Total	275		
	HRQoL	Questionnaires investigating multiple domains[4]	129	74.57	38.62
		Disability specific questionnaire/scales[5]	12	6.94	
		Visual appearance specific questionnaires/scales[6]	20	11.56	
		Pain questionnaire/scale[7]	11	6.36	
		Mental health[8]	1	0.58	
		Total	173		
Qualitative outcome		Total	0		0

[1]Main, secondary, thoracic curve, thoracic kyphosis, lumbar lordosis, thoracolumbar/lumbar

[2]Height, tilt, coronal decompensation, thoracic rib hump/prominence, lumbar prominence, coronal/sagittal balance

[3]Thoracic/lumbar bend, trunk shift/translation/rotation

[4]SRS, CHQ. SF-36, Global outcome score, Global rating of Change (GRC), EQ-5D-dimensions, bracing questionnaire), quality of recovery score—QOR-9, Questionnaire on satisfaction

[5]Functional disability index, Oswestry disability index, Global back disability question, Roland-Morris Disability Questionnaire (RDQ)

[6]Walter reed visual assessment, trunk appearance perception scale (TAPS), body image disturbance questionnaire (BIDQ), spinal appearance questionnaire (SAQ), OFFER (129 standardized self report instrument to evaluate body satisfaction and self image), MBSRQ (69 item self report inventory measuring satisfaction with physical appearance, health and fitness)

[7]Japanese Orthopedic Association Back Pain Evaluation

[8]State-trait anxiety inventory child form (STAIC), Pain catastrophizing scale-schild form (PCS-C), State-Trait Anxiety Inventory-Parent Form (STAIP), Pain Catastrophizing Scale-Parent Form (PCS-P)), coping scale/locus of control

Papers that investigated multiple subcategories had a tally given to each. This tally adds up to more than the 158 papers reviewed, as some papers reported multiple outcome measures

Table 3 Outcome measures investigated for different treatment types

Treatments	Quantitative outcome measures			
	Radiographic		HRQoL	
	Total tally	Percentage (%)	Total tally	Percentage (%)
Surgery	106	50.48	104	49.52
Bracing	24	57.14	18	42.86
Physiotherapy/physical activity	10	58.82	7	41.18
Combination of physiotherapy and bracing	4	50.00	4	50.00
Other	0	0	1	100

as a proxy of success, accounting for 49.30% of all surgical interventions, 60.53% of bracing interventions, and 58.82% of physiotherapy or physical activity interventions. Likewise, an analysis of intervention versus specific HRQoL subcategory domains was conducted. "Questionnaires investigating multiple domains" accounted for 78.74% of all surgical interventions, 69.23% of bracing interventions, and 53.85% of physiotherapy or physical activity interventions (Table 4).

Discussion

Based on the results, many individual studies each define and investigate a distinct outcome measure for successful AIS treatment. However, there is a lack of reviews that collate and analyze these various definitions. This scoping review seeks to create a more broad and inclusive definition of successful AIS treatment that identifies shortcomings of existing measures to better capture the psychosocial impacts on patient outcomes.

Evaluating the clinical utility of quantitative radiographic outcomes in defining successful AIS treatment

Based on the analysis, quantitative radiographic outcomes (61.38%) were the most frequently used measure in evaluating scoliosis treatment success, followed by quantitative

Table 4 Subcategory outcome measurements for different treatments

Treatment		Radiographic outcomes				Quantitative HRQoL outcomes					
		Cobb angle	Trunk shape/alignment	Flexibility/movement	Total	Questionnaires investigating multiple domains	Disability specific questionnaire/scales	Visual appearance specific questionnaires/scales	Pain questionnaire/scale	Mental health	Total
Surgery	Tally	106	54	55	215	100	9	9	8	1	127
	Percentage (%)	49.30	25.12	25.58		78.74	7.09	7.09	6.30	0.79%	
Bracing	Tally	23	7	8	38	18	3	4	1	0	26
	Percentage (%)	60.53	18.42	21.05		69.23	11.54	15.38	3.85	0	
Physiotherapy/physical activity	Tally	10	3	4	17	7	0	5	1	0	13
	Percentage (%)	58.82	17.65	23.53		53.85	0	38.46	7.69	0	
Combination of physiotherapy and bracing	Tally	4	0	2	6	4	0	2	0	0	6
	Percentage (%)	66.67	0	33.33		66.67	0	33.33	0	0	
Other (plan of care protocol)	Tally	0	0	0	0	0	0	0	1	0	1
	Percentage (%)	0	0	0		0	0	0	100	0	

HRQoL measurements (38.62%). Notably, no qualitative HRQoL measurements were recorded (Table 2). In line with this, the literature indicates that radiographic measurements are the gold-standard for AIS diagnosis by excluding alternate underlying causes, characterizing the type of spinal curvature, determining the flexibility of curvature, and following disease progression [165]. In fact, a definitive diagnosis and the subsequent monitoring of patients with AIS cannot be made without imaging [166]. While a variety of radiographic information is available, our analysis indicated that regardless of the intervention used (surgery, bracing, physiotherapy/physical therapy or combination of physiotherapy and bracing), the Cobb angle was the most common proxy of success, in comparison to the measures of trunk shape/alignment and flexibility/movement (Table 4). The Cobb angle is arguably the most important radiographic measure, with its primary clinical utility in determining curve progression risk, diagnosis establishment, treatment selection and monitoring change over time [166–168]. The Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT) consensus defines conservative modes of scoliosis treatment success as a curve progression (stabilization) of $\leq 5°$ or a curve decrease (correction) of $\geq 6°$ at the end of treatment [122, 169, 170]. On the other hand, surgical interventions aim to terminate the progression of AIS, achieve maximum permanent correction of the 3D deformity, promote appearance by balancing the trunk, and keep lower incidence rate of short-term and long-term complications [171].

While the Cobb angle is a necessary measurement for diagnosing and monitoring AIS, it is important not to be over reliant on this single measure, as it has its own limitations. Studies investigating inter- and intra-observer reliability indicate the measurement error of the Cobb angle approximates to 3°–5° [172]. This degree of variation may interfere with the diagnosis and type of treatment pursued, which may ultimately have an impact on patient outcomes. Alternate radiographic measurements such as vertebral rotation, when used in conjunction with the Cobb angle, may enhance clinical utility by playing an integral role in AIS evaluation by predicting curve correction, decompensation, and progression [173, 174]. However, there is still a lack of conclusive evidence that other long-term patient outcomes (such as function, quality of life, self-image, pain, etc.) in those with AIS are affected by improvements in radiographic outcomes [174]. In fact, research has indicated that the Cobb angle has limited prognostic value and is poorly related to overall quality of life, degree of morbidity, and pain experienced by the patient [122, 172].

Evaluating the clinical utility of quantitative HRQoL outcomes in defining successful AIS treatment

In light of increasing emphasis and recognition of patient-reported outcomes, quantitative HRQoL measures that explore the psychosocial impacts of AIS have become mainstay in evaluating treatment success amongst clinicians [175]. Our analysis corroborates this, showing approximately equal radiographic and quantitative HRQoL measures amongst the different schools of treatment (Table 3). Moreover, within each treatment approach, "Questionnaires investigating multiple domains" was the primary quantitative HRQoL outcome measure (Table 4). Particularly, the Scoliosis Research Society questionnaire (SRS) was the most extensively used questionnaire in this category, likely due to its high reliability, internal consistency, and reproducibility that is supported by the literature [176].

The most recent version, SRS-22, measures 5 domains: pain, function/activity, self-image/appearance, mental health, and satisfaction with management. Each domain is rated using a Likert-type scale of 1–5 where a score of 1 denotes "none" and 5 denotes "severe", for a total score of 25. Although the SRS is a widely validated measurement tool, being a Likert-type scale, it is not without limitations. Particularly, there is a high degree of subjectivity, where perceived distances between the response categories and the interpretation of the values may vary by respondent [176]. Additionally, extremes of Likert-type responses are frequently avoided in favor of neutral or central choices, thereby artificially narrowing the range of responses [177]—potentially misrepresenting true patient experiences.

In this paper, we also identified other quantitative HRQoL measures investigating specific isolated domains such as disability, visual appearance, pain, and mental health. While the questionnaires investigating multiple domains captured a large portion of an AIS patient's subjective experiences, some aspects present within these specific questionnaires were missed. Thus, a combination of these questionnaires may be of greater clinical utility in evaluating AIS patient experiences.

The value of thematic analysis in capturing AIS patient biopsychosocial experiences

Above all, by categorizing the HRQoL into 5 distinct domains, the SRS may fail to appreciate the true complex psychosocial experiences of AIS patients. HrQoL questionnaires are strictly a quantitative measure of the biopsychosocial outcomes of AIS and thus are limited in capturing the nuances of AIS patients' lived experiences.

In contrast, thematic analysis is a qualitative measure that has been increasingly used to address this limitation. This approach involves systematically coding and identifying patterns in a data set (written or verbal discussions) to develop overarching themes. It is particularly suited in the analysis of interview transcripts and when used with an inductive approach, lends to a more accurate and in depth account of AIS patient biopsychosocial experiences.

The call for a biopsychosocial approach emerged out of dissatisfaction with historic biomedical models that neglected to appreciate health and illness as a result of a complex interaction between biological, psychological and social factors. At the heart of the biopsychosocial model is the emphasis of patient-centered framework and a collaborative approach to care amongst healthcare professionals. The model underpins that disease can affect social, personal, physical health and emotional contexts for an individual, with each domain heavily influencing the other. It predicts that some consequences of disease can be addressed beyond physical management; moreover, it suggests that addressing social challenges, psychological attitudes or behavior can alter illness pathology and transform the quality of life for patients. With chronic diseases accounting for a great proportion of morbidity, there is an increase in health care resources directed to address patient quality of life and disease management. However, studies have demonstrated that improvements in patient-reported outcomes and reduction of healthcare cost have not advanced despite increasing disease burden under a biomedical approach strictly. Consequently, there is a need for greater understanding and utilization of the biopsychosocial model to improve patient outcomes [178].

A recent qualitative study by Motyer and colleagues attempted to address this gap amongst adolescent pre-surgical AIS patients through thematic analysis of qualitative interviews with AIS patients. Thematic analysis allows for the development of detailed psychosocial experiences of AIS patients through systematic coding of interview transcripts [179].

Whilst the SRS does assess the degree of visual appearance dissatisfaction, it overlooks the link between AIS patients' own visual dissatisfaction and its implications on social relations and fears of being different. Motyer and colleagues describe that visual dissatisfaction in AIS patients are more pronounced in social situations as opposed to when they are alone. Particularly, AIS patients described apprehension and challenges in disclosing their diagnosis, which seemed to further exacerbate visual dissatisfaction [179]. Likewise, although the SRS domain "Mental health" attempts to assess self-confidence and self-esteem, it fails to capture the dynamic feelings of social isolation, desire for reassurance, and fear due to limited knowledge of their condition as described in Motyer's study.

These key themes explored in Motyer and colleagues' study underline the limitations of quantitative HRQoL measures in fully capturing the dynamic psychosocial experience and concerns of AIS patients—to what extent can a numerical value capture the diverse and rich AIS patient narratives? Whilst these questionnaires are undoubtedly useful, it is apparent that thematic analysis can create deeper connections and narratives that appreciate the full patient biopsychosocial experience and concerns. It is paramount then, that clinicians consider and inquire into the patient's perspective regarding concerns, feelings, and goals from treatment to provide optimized care.

A lack of the use of the biopsychosocial approach in AIS treatment is evident and underlines the importance of considering the intersectionalities of biological, psychological and social factors in treating patients. Current AIS treatment approaches often place spine surgeons as the primary care providers for patients in the pre- and postoperative stages. While several studies have documented the adverse impact that patient psychosocial distress has on treatment outcomes [180–182], few spinal surgeons have been shown to evaluate these measures [183].

A recent prospective study conducted by Daubs and colleagues evaluated the clinicians' ability to categorize their patients' psychological distress level. They identified that large proportions of patients that presented for spinal evaluation had some levels of psychological distress. Moreover, spine surgeons were found to often underestimate and demonstrate low sensitivity rates in detecting their patients' distress. The study underlines the adverse relationship of psychological distress and spinal conditions, and the importance for spine surgeons to be more aware of psychological distress in patients [184].

Taken together, the invaluable role of interviews in eliciting biopsychosocial experiences of AIS patient demonstrated by Motyer and colleagues, along with the findings that spine surgeons have low sensitivity rates for detecting patient distress, indicate a role for qualitative methods such as interviews in defining a patient perspective of AIS treatment success. This suggests that thematic analysis has great clinical utility in providing health care providers invaluable insight into the biopsychosocial challenges and limitations of living with AIS, thereby eliciting a direct means of addressing the concerns to foster true patient-centered care. Strategies could include fine tuning healthcare resource allocation that reflect the shortcomings of existing AIS treatment paths. Moreover, thematic analysis can also reveal the positive experiences and unique biopsychosocial adaptations that can be protective factors that clinicians can incorporate in caring for AIS patients.

In light of this, we believe that more conversations and discussions need to occur with AIS patients to learn about the positive and negative biopsychosocial impacts of living with the condition. Moreover, the approach to research should be done in a joint collaborative fashion placing the stakeholders, AIS patients, at the true center in creating reforms in the standard of care. By incorporating a thematic analysis approach, we strongly believe that a greater appreciation of AIS patient concerns and desires can be gained for clinical utility.

Limitations of this scoping review

Despite efforts in undertaking a comprehensive investigation and analysis of the current literature regarding outcome measures used as proxies of successful AIS treatment, this scoping review is not without limitations. Although 2 large databases (EMBASE and MEDLINE) were searched, we recognize that relevant studies may still have been missed in this scoping review. Only primary literature written in English and published in peer-reviewed journals were included in our search. In this study, only articles that explored a specific treatment or intervention to AIS were included. Therefore, papers that discussed potential treatment success measures may have been missed.

Conclusion

In this scoping review, we identified that to date, the literature predominantly attempts to stratify AIS treatment success via either radiographic or quantitative HRQoL means. Notably, no papers employed qualitative measures of describing the psychosocial implications of AIS in determining what successful AIS treatment is. Moreover, it was found that the Cobb angle was the most predominantly used quantitative radiographic measure, whilst "Questionnaires with multiple domains", was the most favored outcome measure within quantitative HRQoL measurements. Although quantitative measures undoubtedly play an important role in the clinical diagnosis, management, and evaluation of how AIS impacts patients, it is apparent that numerical values alone cannot describe and integrate the full extent of biopsychosocial experiences. There is increasing value to using qualitative methods, such as thematic analysis, to deliver a more thorough patient narrative, aligning with the biopsychosocial model. Future research should seek to investigate qualitative interpretations of treatment success from the patient perspective in order to aid clinicians in developing a more patient-oriented care approach.

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Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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