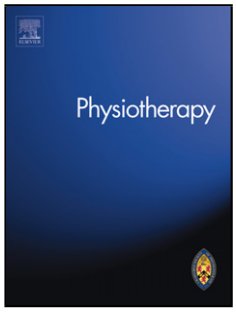

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Effectiveness of scoliosis-specific exercises for adolescent idiopathic scoliosis compared with other non-surgical interventions: a systematic review and meta-analysis

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Abstract

Study design Systematic review and meta-analysis.

Objective To assess the effectiveness of scoliosis-specific exercises (SSE) on adolescent idiopathic scoliosis (AIS) compared with other non-surgical interventions.

Background AIS is a complex deformity of the spine that develops between the age of 10 years and skeletal maturity. SSE are prescribed to patients to reduce or slow curve progression, although their effectiveness is unknown.

Methods Electronic databases were searched for relevant studies. Randomised controlled trials were eligible if they compared SSE with non-surgical interventions for individuals with AIS. Three authors independently extracted data, evaluated methodological quality and assessed the quality of evidence. Meta-analysis was performed where possible; otherwise, descriptive syntheses are reported.

Results Nine randomised controlled trials were included. Four had a high risk of bias, three had an unclear risk and two had a low risk. Very-low-quality evidence indicated that SSE improved some measures of spinal deformity, function, pain and overall health-related quality of life (HRQoL). Very-low-quality evidence suggested that SSE had no effect on self-image and mental health. Very-low-quality evidence showed that bracing was more effective than SSE on measures of spinal deformity. However, SSE showed greater improvements in function, HRQoL, self-image, mental health and patient satisfaction with treatment. No differences were found for pain or trunk rotation.

Conclusions SSE may be effective for improving measures of spinal deformity for people with AIS, but the evidence is of very low quality. Future studies should evaluate relevant clinical measures and cost-effectiveness using rigorous methods and reporting standards.

Keywords: Scoliosis; Adolescents; Exercise therapy; Review; Meta-analysis

<A>Introduction

Adolescent idiopathic scoliosis (AIS) is a three-dimensional deformity of the spine of unknown cause, estimated to affect 2% to 3% of the general population between the age of 10 years and skeletal maturity [1,2]. The condition can result in functional limitations, pain, cosmetic concerns and possible progression during adulthood, resulting in decreased quality of life [3]. The most frequently used measure of spinal curvature is the Cobb angle, which measures the magnitude of the spinal curvature in the frontal plane using radiographs [2].

Currently, the mainstay of management in the USA and UK is surgery for patients with severe curvatures, and monitoring, bracing and advice for those with mild-to-moderate curvatures [4–6]. In mainland Europe, scoliosis-specific exercises (SSE) are often used to manage patients with mild-to-moderate curvatures, with or without bracing, in an attempt to reduce the need for surgical intervention [3,7,8]. Surgery is costly and not without risks so, if surgery can be avoided by slowing the progression or reversing the curvature through the use of SSE, this is an appealing treatment option [6].

To date, evidence to support the effectiveness of SSE is limited. A previous systematic review concluded that there is inconclusive evidence on the effectiveness of exercise on AIS [2]. The review included one low-quality randomised controlled trial (RCT) and a number of small observational studies [2]. A number of RCTs have been published recently, warranting an update of the literature.

The aim of this systematic review was to evaluate the effectiveness of SSE for individuals with AIS compared with other non-surgical interventions in terms of spinal curvature, pain, adverse events, function, quality of life and financial costs.

<A>Materials and methods

<B>Data sources and searches

This study replicated the search strategy used by the Cochrane Review [2] from inception to 11th January 2018 in the following databases: CENTRAL (The Cochrane Library and the Cochrane Back Review Group Trials Register), MEDLINE, EMBASE, CINAHL, SportDiscus, PsycInfo, PEDro and Index to Chiropractic Literature (see Appendix 1 in online supplementary material for details on the search strategy).

Potential abstracts were screened using the selection criteria, and full-text articles were obtained for those that appeared eligible. These were examined by independent assessors and checked for eligibility.

<B>Study selection

Studies were eligible if they were RCTs evaluating SSE in participants with AIS (defined as a primary Cobb angle ≥10º) aged between 10 years and skeletal maturity. SSE were defined as 'specific movements performed with a therapeutic aim of reducing the deformity' [2]. Sports, active recreational activities and general physiotherapy were not considered to be SSE, and studies primarily evaluating these types of activities were excluded. RCTs including participants with non-idiopathic scoliosis (congenital, neurological, posttraumatic, etc.) were also excluded.

Studies were eligible if control interventions were of a non-surgical nature (e.g. bracing, electrical stimulation, manual therapy, generalised exercise, sports, active recreational activities, advice or waiting list). Eligible studies needed to include at least one of the following common outcomes for any length of follow-up.

<B>Primary outcomes

- Cobb angle (in degrees)
- Angle of trunk rotation (ATR) (in degrees)

<B>Secondary outcomes

- Condition-specific function/quality of life/disability as measured by validated questionnaires [e.g. Scoliosis Research Society-22 (SRS-22)].
- Pain as measured by visual analogue scale or other validated questionnaires.
- Cosmesis/appearance issues using validated measures (e.g. Spinal Appearance Questionnaire) [10].
- Cost-effectiveness measures [e.g. cost utility using EuroQol-5 dimension (EQ-5D)].
- Rates of surgical procedures or brace prescriptions.
- Adverse events.

<B>Data extraction

Data were extracted independently; discrepancies were discussed and resolved with a third reviewer. Data on participant, study, intervention characteristics and outcome measures were extracted. The dosage or schedule of the SSE interventions was defined by volume (number of sets and repetitions), frequency (number of training sessions per week), duration (in weeks, months or years) and type of exercise performed (muscle groups involved or type of exercise such as progressive loading). The most vs least intensive group approach was used when three or more groups were investigated [9].

<B>Risk of bias assessment

Eligible studies were assessed for risk of bias at study level using the criteria published by the Cochrane Back Review Group [10]. This was done independently and findings were compared to achieve consensus. Discrepancies were resolved with a third reviewer. A study was considered to be at low risk of bias if it fulfilled three key criteria related to randomisation, allocation concealment and outcome assessor blinding [10,11].

<B>Data analysis

If an outcome was reported by more than one study, mean differences (MD) and standard deviations (SD) were extracted for continuous measures to perform meta-analysis. Standardised mean differences (SMD) were used for studies measuring the same construct using different tools. For dichotomous outcomes, the number of events and participants in each treatment group were extracted to calculate the relative risk (RR) and confidence intervals (CI) [11]. Comparisons of SSE vs other non-surgical treatments were meta-analysed when the interventions were considered to have sufficient clinical homogeneity.

Meta-analysis was performed using a random effects model with RevMan 5.3 Software (Cochrane IMS), and subgroup analysis was performed by the location of the curve. If required, measures were corrected for differences in the direction of the scales. Comparisons of SSE vs standard care where the conservative management for the standard care group had similar intervention components were meta-analysed.

<B>Assessment of heterogeneity

Heterogeneity was explored using the Chi-squared test and I^2 statistic, with a probability value of <0.05 indicating significant heterogeneity. Findings were interpreted as follows: I^2 of 0% to 30%, unimportant heterogeneity; I^2 of 30% to 60%, moderate

heterogeneity; I^2 of 50% to 90%, substantial heterogeneity; and I^2 of 75% to 100%, high heterogeneity [11].

<B>Quality of evidence

The quality of evidence for each outcome was rated based on the system developed by the GRADE (Grading of Recommendations, Assessment, Development and Evaluations) collaboration [10].

Factors that may decrease the quality of the evidence are high risk of bias, inconsistent results across studies, lack of generalisability (indirectness) and imprecise estimates of outcome measures. The quality rating of the evidence started at high and was downgraded to moderate, low or very low evidence for a maximum of three levels for all factors [12] using the following guidelines:

(i) risk of bias – this was downgraded if >25% of the participants were from studies with a high risk of bias;

(ii) inconsistency of results – this was rated down if significant heterogeneity defined as I^2>50% was present, or if large differences in magnitude and direction of effects between studies was present;

(iii) indirectness (i.e. generalisability of the findings) – this was downgraded if >50% of the participants were outside the target group; and

(iv) imprecision – in accordance with Mueller and Rubinstein [12], single studies with <400 participants for continuous outcomes or <300 participants for dichotomous outcomes were considered as 'low-quality evidence', and 'very-low-quality evidence' if there were further limitations (of high risk of bias, inconsistency and/or indirectness) on the GRADE score.

<A>Results

<B>*Search results*

The process of identifying eligible studies and excluding ineligible studies is reported in Fig. 1 and Appendix 2 (see online supplementary material). Nine studies were identified; one study [13] reported the primary [14] and secondary [15] outcomes separately.

<insert Fig 1 near here>

<B>*Characteristics of included studies*

Characteristics of the included studies are described in Table 1. These studies were conducted in Egypt, Brazil, Italy, Turkey, Korea, China and Canada [9,14–22]. Sample sizes recruited ranged from 20 to 110, with a total of 480 participants recruited into studies. At follow-up, there were 459 participants. These included 342 females (75%) and 117 males (25%) with a mean baseline age of 10 [17] to 16 years [20].

<insert Table 1 near here>

The median Cobb angle of participants recruited to studies was 26.0° (interquartile range 23.0 to 30.3). All studies evaluated different types of SSE with some similarities between the approaches used. The concept of active self-correction underpinned the approaches used in seven studies [9,17–20,22,23], with one of these studies facilitating exercises with manual therapeutic techniques [17]. Of the two remaining studies, one included stretches of tightened structures on the concave side of the curvature, and strengthening of trunk muscles with and without exercises to correct adapted forward head posture [16]. The other study evaluated a gymnastic-based exercise programme where

participants exercised in asymmetrical postures to correct the S-shaped curvature alongside use of electrostimulation and traction [21].

There was some variation in the frequency of exercise sessions conducted, from daily [21] to every other day [18]. Greater variation was found for the duration of exercise interventions, ranging from 3 weeks [24] up to a mean duration of 42 months [18]. The length of follow-up ranged from 10 weeks post-treatment [19] to 12 months after skeletal maturity [18]. There were no drop-outs in five studies [9,17,19–21], and the attrition rate was <20% in the remaining studies [16,18,22,23].

Standard care interventions described in Table 1 included no treatment [17], 'traditional rehabilitation' (e.g. breathing exercises, stretching and strengthening of spinal muscles) [16,18–20], Pilates [19], physiotherapy (electrostimulation, traction and postural correction) [21], and observation with or without bracing [9,23]. One study [22] administered a strict bracing programme (bracing: 23 hours/day for 12 months) to the control group that was not administered to the intervention group. It was felt that this comparator (bracing) was fundamentally a different approach to the control interventions used in other studies, and it was inappropriate to include in the meta-analysis due to clinical heterogeneity. This was confirmed by a sensitivity analysis in which the inclusion of the study by Zheng *et al.* [22] introduced unacceptable levels of statistical heterogeneity. Two other studies [14,19] also permitted bracing as part of standard care, but it was available to participants in both arms of the study.

<B>Quality assessment

The results of the methodological assessment are shown in Table 2. Two studies were at low risk of bias [18,23]. Three studies had an unclear risk of bias [9,16,22]. Four studies were considered to be at high risk of bias, primarily due to failure to report adequate methods

of random sequence generation, concealment of allocation and failure to blind assessors [17,19–21]. Two studies [18,23] reported the use of blinded outcome assessors. Two studies [18,23] reported information on adherence to exercise programmes. No study masked the participants or treatment providers, but the nature of the interventions made this practically impossible. Three studies [15,19,20] reported details on co-interventions.

<insert Table 2 near here>

<B>Effect of interventions

<C>Spinal curvature (Cobb angle)

The primary outcome for this review was the Cobb angle measured by eight studies [9,14,17–22] (Table 3a), with data analysed from a total of 395 participants. The results are presented in two categories: SSE vs control (non-SSE exercises or standard care) and SSE vs bracing.

<insert Table 3 near here>

<D>SSE vs control (non-SSE exercises or standard care)

Seven studies compared SSE with a different type of exercise or standard care. The results from six studies (*n*=297) that showed consistent evidence of improvement in the Cobb angle irrespective of the location of the curve were pooled [14,17–21]. At follow-up, particiapts who underwent the SSE intervention had, on average, a smaller thoracic Cobb angle (*n*=125, MD -6.9º, 95% CI -9.0 to -4.7), lumbar Cobb angle (*n*=105, MD -7.2º, 95% CI -10.0 to -4.5) and main curve (location undefined) (*n*=172, MD -5.0º, 95% CI -9.0 to -1.1) compared with participants who underwent standard care (Fig. 2).

<insert Fig 2 near here>

The remaining study [9] (*n*=45) showed small but significant improvements in Cobb angle across three groups of supervised SSE and home-based SSE vs standard care. However, the result was presented as the median values of the Cobb angle, suggestive of skewed data unsuitable for meta-analysis.

One study [18] reported categorical outcomes for participants who demonstrated improvement of >3° in their Cobb angle. The RR for improvement for participants aged <13 years was 7.6 (95% CI 2.5 to 22.8). This suggests that participants who received SSE were, on average, seven times more likely to experience improvement in their Cobb angle compared with those who received standard care. The RR for deterioration was 0.3 (95% CI 0.1 to 1.0), indicating that there was no difference in the risk of deterioration in the Cobb angle among participants who received SSE compared with participants who received standard care. For patient stability, the RR was 0.3 (95% CI 0.2 to 0.7) [18], suggesting that participants receiving SSE were more likely to present with stable curves than participants who received standard care [18] (see Table 3b).

A similar trend was observed among participants aged ≥13 years. The RR for improvement was 26.4 (95% CI 1.7 to 413.8), suggesting that participants who received SSE were, on average, 26 times more likely to experience improvement in their Cobb angle compared with those who received standard care. The RR for deterioration was 0.1 (95% CI 0.0 to 0.6), indicating that the risk of deterioration in the Cobb angle was less among participants who underwent SSE compared with participants who received standard care. For patient stability, the RR was 0.6 (95% CI 0.3 to 1.4) [18], suggesting that there was no difference in stability among participants who received SSE compared with participants who

received standard care (see Table 3b). Overall, there was low-quality evidence suggesting that participants who received SSE (aged <13 years and ≥13 years) demonstrated lower risk of curve progression compared with participants who received standard care [18].

<D>SSE vs bracing

One study (*n*=53) compared SSE with a strict bracing regimen, and reported a smaller mean Cobb angle in the bracing group at the 12-month evaluation (MD 2.7º, 95% CI 0.2 to 5.1) compared with the SSE group (Table 4a). A greater average reduction of the Cobb angle was also reported at the 6-month evaluation (MD 2.5º, 95% CI 0.8 to 4.2) and 12-month evaluation (MD 3.6º, 95% CI 0.8 to 6.4) for the bracing group compared with the SSE group (see Table 3b) [22].

<C>Angle of trunk rotation

<D>SSE vs control (non-SSE exercises, standard care)

Three studies [9,18,19] reported data for measures of ATR, providing a total of 153 participants (Table 4b). The pooled analysis showed no difference in mean thoracic ATR between SSE and standard care groups at follow-up (one study, *n*=25, MD -1.4º, 95% CI -2.5 to 5.3). However, participants who received SSE had, on average, a smaller lumbar ATR (one study, *n*=25, MD -4.4º, 95% CI -7.6 to -1.2) and main curve (location undefined) ATR (two studies, *n*=128, MD -3.2º, 95% CI -3.6 to -2.8) at follow-up compared with participants who received standard care (Fig. 3 and Table 3c).

<insert Table 4 and Fig 3 near here>

<D>SSE vs bracing

One study [22] reported no between-group differences for ATR at 6-month follow-up (MD 0.3°, 95% CI -0.4 to 1.0) and 12-month follow-up (MD 0.2°, 95% CI -0.5 to 0.9) (*n*=53) using SSE and bracing as comparators (Table 3c).

<C>Function

The SRS-22 function subscale [score: 1 (worst) to 5 (best)] was used by four studies [15,16,18,19] to provide self-reported data on functional outcomes. One study used the Functional Rating Index [scale: 40 (worst) to 0 (best)] to measure function [16].

<D>SSE vs control (non-SSE exercises or standard care)

Four studies compared function between SSE and a different type of exercise or standard care [15,16,18,19]. Data from three studies were combined [16,18,19] (Table 4 and Fig. 5). Participants who underwent SSE reported better function at follow-up than participants who received the control intervention (*n*=192, SMD 1.9, 95% CI 0.5 to 3.4).

<insert Fig 5 near here>

One study [15] reported improvement at 6 months for the SSE group compared with the control group, but presented data that were transformed to the power of four and were not suitable for inclusion in the meta-analysis. The authors attempted to contact the corresponding author for the raw data, but there was no reply.

<D>SSE vs bracing

A significant between-group difference in function was reported [22] when comparing bracing with SSE. Participants who received SSE reported better function at 6-month follow-

up (MD 0.3, 95% CI 0.2 to 0.4) and 12-month follow-up (MD 0.2, 95% CI 0.1 to 0.2), respectively (Table 4).

<C>Pain

Four studies [15,18,19,22] presented data using the SRS-22 pain subscale [score: 1 (worst) to 5 (best)].

<D>SSE vs control (non-SSE exercises or standard care)

Three studies [15,18,19] compared pain between SSE and a different type of exercise or standard care. Data from two studies [18,19] were pooled, involving a total of 123 participants in a meta-analysis (Table 4). Participants who received SSE showed better pain scores than participants who received standard care (MD 0.5, 95% CI 0.4 to 0.7) (Fig. 4). Results from the other study [15] also showed small but significant improvements in pain. However, the data were transformed to the power of four and were not suitable for inclusion in the meta-analysis.

<D>SSE vs bracing

No difference in pain scores was observed between participants who received SSE and participants who received bracing [22] at 6-month follow-up (MD -0.0, 95% CI -0.1 to 0.0) and 12-month follow-up (MD 0.0, 95% CI -0.1 to 0.1) (Table 5).

<insert Table 5 near here>

<C>Self-image

<D>SSE vs control (non-SSE exercises or standard care)

Data from three studies [15,18,19] using the SRS-22 self-image subscale [score: 1 (worst) to 5 (best)] were combined, with a total of 167 participants (Table 4). No between-group differences were found in follow-up scores (MD 0.4, 95% CI -0.3 to 1.1] (Fig. 6). Two studies reported on other measures of self-image: Spinal Appearance Questionnaire [15], Trunk Appearance Perception Scale and Posterior Trunk Symmetry Index [19] (Table 5). The results showed no significant difference between SSE and standard care groups for measures of cosmesis [15,19].

<insert Fig 6 near here>

<D>SSE vs bracing

A significant between-group difference (MD 0.9, 95% CI 0.8 to 0.9) in favour of the SSE group was reported for the SRS-22 self-image subscale [score: 1 (worst) to 5 (best)] at 6-month follow-up [22] compared with bracing (Table 4).

<C>Mental health

<D>SSE vs control (non-SSE exercises or standard care)

Data from two studies [18,19] that used the SRS-22 mental health subscale [score: 1 (worst) to 5 (best)] were combined. There was no difference between the SSE and control interventions (*n*=123, MD 0.3, 95% CI -0.9 to 1.6) (Table 4 and Fig. 7).

<insert Fig 7 near here>

<D>SSE vs bracing

A significant between-group difference in favour of the SSE group was reported at 6-month follow-up (*n*=53, MD 0.4, 95% CI 0.3 to 0.6) and 12-month follow-up (*n*=53, MD 0.4, 95% CI 0.3 to 0.5) [22].

<C>Health-related quality of life

<D>SSE vs control (non-SSE exercises or standard care)

Data for total SRS scores [score: 1 (worst) to 5 (best)] from two studies [15,19] were combined, involving a total of 69 participants (Table 4). A small between-group difference in follow-up health-related quality of life (HRQoL) scores was found, favouring the SSE group (SMD 0.3, 95% CI 0.2 to 0.3] (Fig. 8).

<insert Fig 8 near here>

<D>SSE vs bracing

A significant between-group difference in favour of SSE was reported at 6-month follow-up (MD 5.7, 95% CI 4.4 to 7.0) and 12-month follow-up (MD 3.2, 95% CI 2.0 to 4.3) (Table 4) [22].

<C>Satisfaction with management

Two studies [18,22] reported data on satisfaction with treatment post-intervention, but data were not combined due to significant clinical heterogeneity in the control interventions (Table 4).

<D>SSE vs control (non-SSE exercises or standard care)

One study [18], comparing SSE with a different type of exercise, provided results indicating greater satisfaction following SSE (MD 0.7, 95% CI 0.5 to 0.9). A second study [22], comparing SSE with bracing, also suggested greater satisfaction with treatment following SSE at 6-month follow-up (MD 0.4, 95% CI 0.1 to 0.7).

<C>Other outcomes

<D>Adverse events

One study [18] reported an increase in short-term spinal pain among participants in both arms of the study [SSE (*n*=11) and standard care (*n*=14)].

<D>Compliance

Two studies [19,22] reported no difference in compliance rates across the two treatment arms between those receiving SSE and bracing as part of standard care treatment. Another study [14] reported adequate compliance among individuals who completed the SSE treatment until follow-up; however, poor compliance was observed across the whole SSE treatment arm. No report was provided for standard care.

<D>Need for other treatments and cost-effectiveness

No study reported on the progression of a curve resulting in the need for surgery or bracing, resource use or cost-effectiveness (see Appendix 3 in online supplementary material for details of other outcomes not relevant to this review).

<B>Summary of findings – GRADE levels of evidence

The comparison of SSE with standard care or other types of exercise found very-low-quality evidence that SSE is effective at reducing the Cobb angle (all curve locations)

compared with standard care or other types of non-specific scoliosis exercises (Table 6a). There was also very-low-quality evidence suggesting improvements in clinical outcomes of ATR (lumbar and main curves), function, pain and overall HRQoL in young people with AIS (Table 6b). There was very-low-quality evidence that SSE has no effect on thoracic trunk rotation, self-image and mental health.

<insert Table 6 near here>

When comparing bracing with SSE, there was very-low-quality evidence from one study suggesting that a strict bracing programme was more effective at reducing Cobb angle than SSE. However, there was very-low-quality evidence that participants undertaking SSE had better outcomes in regard to function, quality of life, self-image and mental health. There was very-low-quality evidence that there was no difference between treatments for pain and ATR.

The evidence for each outcome was downgraded due to methodological limitations, inconsistency, differences in populations and/or imprecision (Table 6).

<A>Discussion

This review aimed to estimate the effect of SSE on patients with AIS in terms of measures of spinal deformity and other relevant outcomes such as HRQoL.

<B>SSE vs standard care

For the primary outcomes, the meta-analyses showed that SSE results in lower measures of spinal deformity at follow-up (Cobb angle and ATR) in comparison with other types of exercise or standard care control interventions, although the evidence is of very low

quality. The mean differences reported for Cobb angles were generally greater than the commonly reported minimum detectable change of 6° [25]. Alongside reports of risk ratios from one study indicating greater chances of improvement associated with SSE, this suggests better outcomes with SSE compared with standard care. However, the clinical relevance of these differences and that for ATR remains unclear. While no major risks or adverse events were reported, the lack of high-quality evidence limits the recommendation of SSE as an effective treatment.

For secondary outcomes, the outcomes for HRQoL were synthesised using the SRS-22 subscales. Pain, function and total HRQoL scores showed higher (i.e. better) post-treatment scores following SSE compared with other interventions (MDs 0.5, 1.9 and 0.3 points, respectively). Unfortunately, the level of evidence is of very low quality and these differences may not be clinically important. Previous attempts to define the minimal clinically important difference (MCID) following surgery for the various scales of the SRS-22r have generally produced results that were below the margin of error and/or calculated minimum detectable change (MDC) [26,27]. Pre–post-surgery MDCs between 0.3 and 0.6 points for pain, between 0.4 and 0.8 for function, and of 0.4 for total HRQoL have been reported [26,27]. In contrast, MCIDs of 0.7 for both pain and function post-conservative treatment (including exercise) were higher than MDCs (0.1 to 0.3 points), although the measurement characteristics of the MCID estimates were generally low [28]. The variation in these estimates probably relates to different study populations, treatment interventions and calculation methods. Taking these reports into account, the estimated MD for function appears to reflect a clinically important difference, whereas the estimated MDs for pain and total HRQoL appear to be of uncertain clinical significance.

There was evidence of no difference in post-treatment scores between SSE and other types of exercises or standard care for self-image and mental health when comparing SSE

with standard care. The overall impact of observed effect on clinical management [27] is unknown, as most studies in this review did not report adverse events, cost-effectiveness, and the number of participants who still needed surgery or bracing. Similar reports were made in a previous review [29] that sought to explore surgical vs non-surgical techniques in the management of AIS. The authors of that review did not identify any clinical or controlled trials to inform practice.

<B>SSE vs bracing

One study [22] included in this review compared a strict bracing regimen with SSE, and reported that bracing was more effective than SSE in reducing curve progression, with lower mean spinal deformity measures at follow-up reported for bracing. This is supported by evidence from previous reviews [1,4,7,30–35] of observational and controlled studies showing improvements in Cobb angle measurements with bracing. However, the results of the meta-analysis revealed a mean difference between groups of 2.7°, which is below the normally accepted MDC of 6° [25]. Combined with the lack of difference for follow-up ATR angles between groups, the clinical significance of the difference in spinal deformity measures between bracing and SSE based on the present results is uncertain at best.

In general, bracing is a highly burdensome intervention that is difficult to implement in clinical practice due to poor compliance among patients with AIS. This may explain the difference in HRQoL scores, function, self-image, mental health and greater satisfaction with treatment for the SSE group. This is particularly evident in the difference in total HRQoL scores between groups (5.7 points and 3.2 points at 6 and 12 months, respectively), which were much greater than the best estimates of MDC and MCID (0.5 and 0.6, respectively) [26], suggesting a very large clinically important difference favouring SSE. The main driver of this appears to be due to self-image, where mean differences in scores (0.9 points)

favouring SSE are more than double the MCID previously reported post-conservative treatment. However, the differences between groups for other subscales of the SRS-22r were generally small, and did not exceed previously reported MDC and MCID figures [26–28]. To date, the quality of the evidence is still limited and improvements were mostly observed with extended periods of application hindering firm conclusions about bracing vs SSE as a stand-alone management for AIS.

<B>Previous reviews of SSE vs other interventions

Previous systematic reviews evaluating the role of SSE in AIS [2,36–39] have suggested that there is some evidence to support its use, with better outcomes of decreased risk of curve progression compared with groups receiving traditional exercises. However, these reviews were predominantly based on findings from observational studies, and therefore are only suggestive and not definitive. Since the most recent review [2] evaluating SSE and conservative management was conducted, eight RCTs have been published. This allowed the present authors to focus solely on RCTs and undertake a meta-analysis, making it the first review to do so. Therefore, recommendations are based on the highest quality of evidence [5]. However, studies included in this review used different approaches to SSE, often in combination with other interventions, so the authors are not able to recommend one approach over another.

<B>Limitations

Although this review used a sensitive search strategy, assessed quality using the Cochrane guidelines [40], and summarised levels of evidence according to the GRADE procedure [41], there were inherent limitations. The authors were reliant on data from significantly heterogeneous studies that have been found to be at high risk of bias. Secondly,

the grey literature was not explored, and the small number of studies included meant that the authors were unable to explore potential publication biases and bias due to missing results, stratify results by curve presentation, or adjust for contextual factors. Furthermore, most studies had small sample sizes, which could have masked variation due to systematic error or poor precision. In addition, when rating indirectness as a factor for quality of evidence, the authors took a broad approach. That is, outcomes were rated as generalisable when participants had a diagnosis of AIS (regardless of the type of curve presentation and age variations).

A number of implications for future research are highlighted by this review. There is clearly a need for high-quality RCTs to be conducted that adhere fully to the CONSORT [11] and SOSORT [42] guidelines. One RCT is still underway [43], and data from future trials is likely to have an important impact on confidence in the estimate of effect and to change the estimate. A need exists for consistent use of outcomes [42,44,45], and to ensure that these outcomes cover a range of measures that are important to all stakeholders, including cost-effectiveness, rates of bracing and surgery.

<A>Conclusion

Very-low-quality evidence exists to support the use of SSE rather than standard care or other types of exercise for patients with AIS to reduce spinal curvature and trunk rotation, improve pain, function, satisfaction with management and overall quality of life, although it is unclear if the reported differences are clinically relevant. There is very-low-quality evidence indicating no benefit of SSE on self-image and mental health in comparison with standard care or other types of exercise.

The effect of bracing compared with SSE is unclear due to very-low-quality evidence with conflicting outcomes, as some outcomes favour bracing (Cobb angle), some favour SSE

(quality of life, function, self-image, mental health and satisfaction with treatment) and some show no difference (pain and ATR). There are also concerns regarding the clinical significance of some of the reported differences between SSE and bracing.

Well-conducted, long-term studies evaluating cost-effectiveness and clinical outcomes are needed to make definitive clinical recommendations.

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Fig. 1. Flow chart of study selection process – identifying new studies.

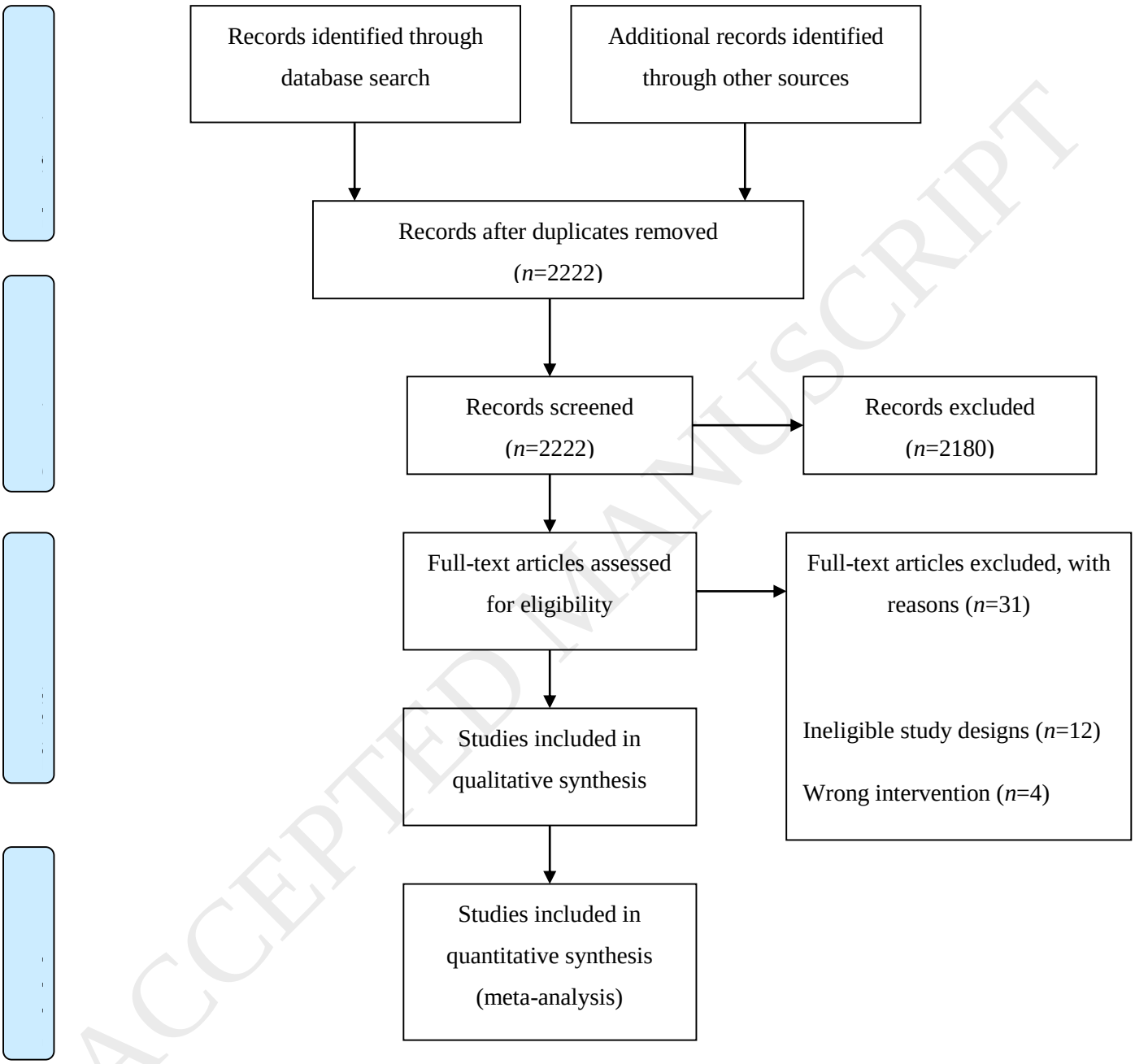
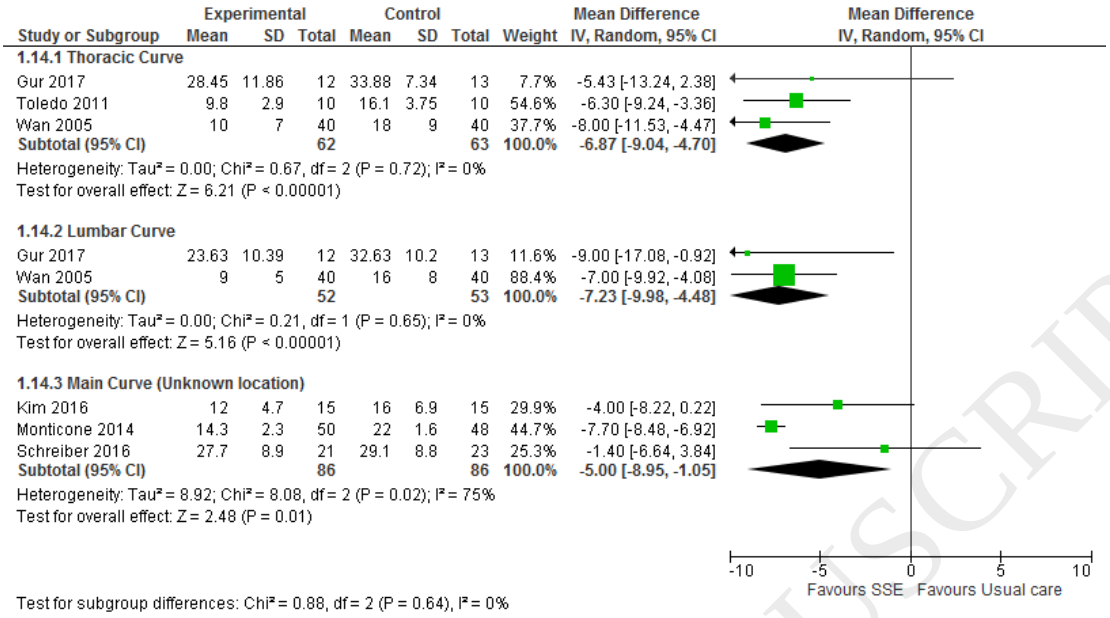
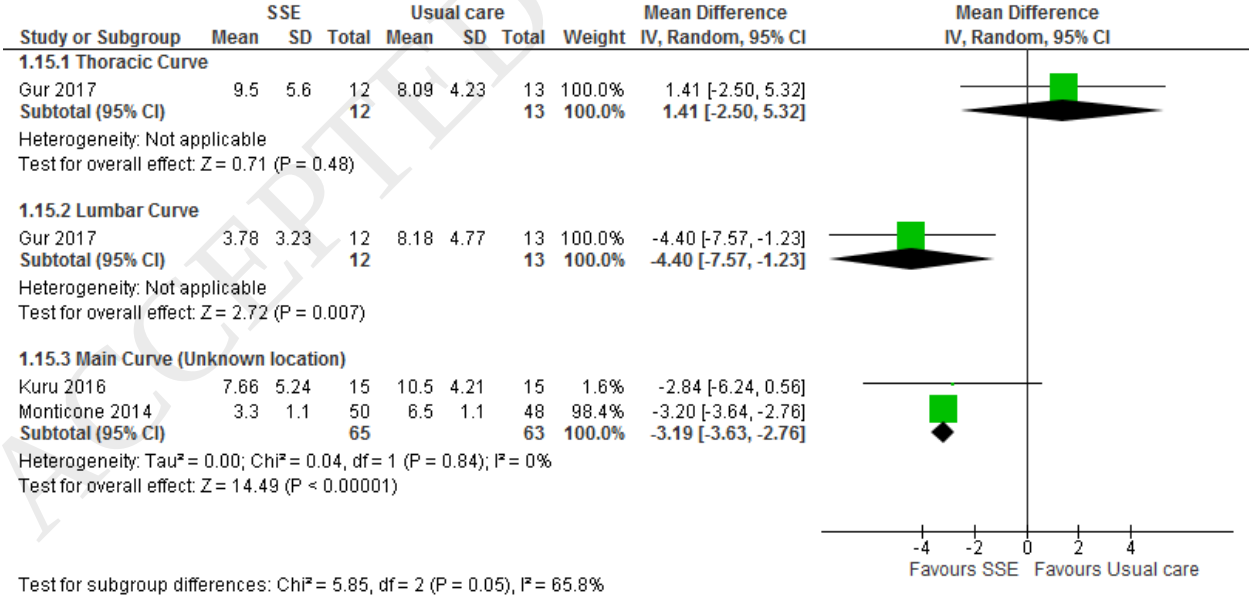


Fig. 2. Forest plot showing subgroup mean differences in Cobb angle between the intervention and standard care arms.



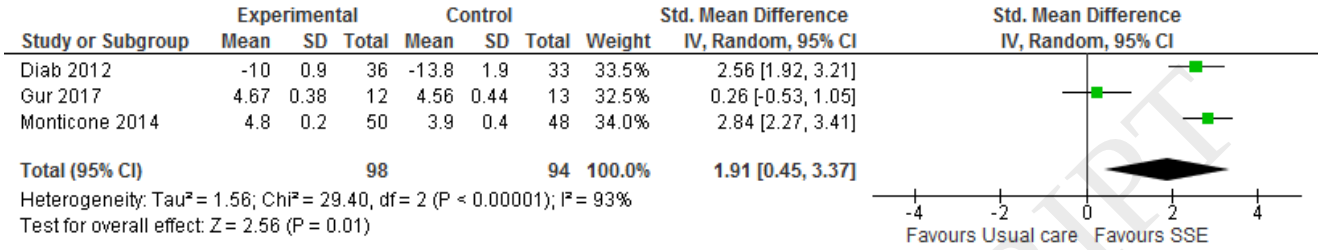
SD, standard deviation; CI, confidence interval; I^2, inconsistency test; SSE, scoliosis-specific exercises.

Fig. 3. Forest plot of showing subgroup mean differences in angle of trunk rotation between the intervention and standard care arms.



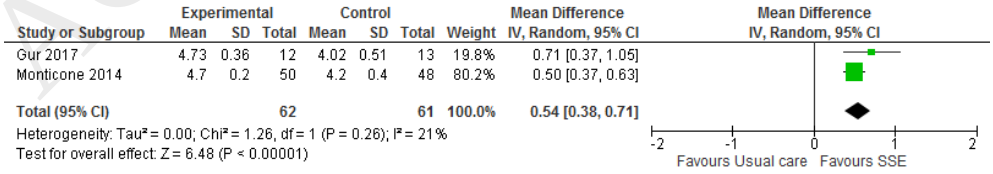
SD, standard deviation; CI, confidence interval; I^2, inconsistency test; SSE, scoliosis-specific exercises.

Fig. 4. Forest plot showing standardised mean difference (SMD) in patient-reported function between the intervention and standard care arms.



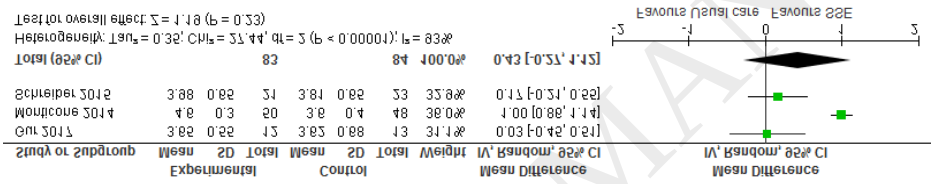
SD, standard deviation; CI, confidence interval; I^2, inconsistency test; SSE, scoliosis-specific exercises.

Fig. 5. Forest plot showing the mean difference in patient-reported pain between the intervention and standard care arms.



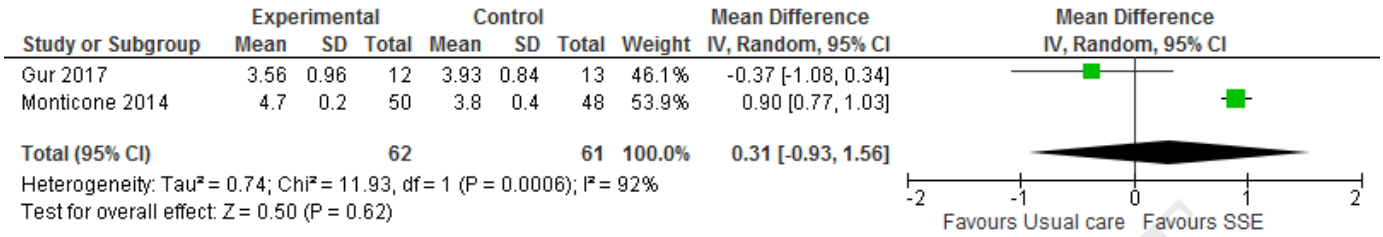
SD, standard deviation; CI, confidence interval; I^2, inconsistency test; SSE, scoliosis-specific exercises.

Fig. 6. Forest plot showing the mean difference in patient-reported self-image between the intervention and standard care arms.



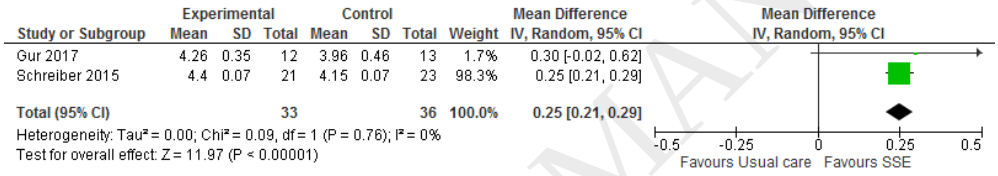
SD, standard deviation; CI, confidence interval; I^2, inconsistency test; SSE, scoliosis-specific exercises.

Fig. 7. Forest plot showing the mean difference in patient-reported mental health between the intervention and standard care arms.



SD, standard deviation; CI, confidence interval; I^2, inconsistency test; SSE, scoliosis-specific exercises.

Fig. 8. Forest plot showing the standardised mean difference in health-related quality of life between the intervention and standard care arms.



SD, standard deviation; CI, confidence interval; I^2, inconsistency test; SSE, scoliosis-specific exercises.

Table 1

Characteristics of the included studies

Study	Sample	Type and size of spinal curves included in the study	Description of the intervention(s)	Outcomes	Results
Wan 2005 [21]	IG: *n*=40 Loss to follow-up=0 15.0 (4.0) years F: 43 (54%) M: 37 (46%)	S-shaped scoliosis excluding C-shaped scoliosis. Mean Cobb angles: 26º (12) and 24º (10) for thoracic and lumbar segments, respectively	Intervention: gymnastic exercise programme stretching out concave side of curve. Each step is repeated 10 times up to 30 repetitions, holding the position for 30 seconds with 30-second rests, repeated 2x or 3x. Volume and intensity were increased gradually by attaching 0.15- to 0.25-kg bags on the left leg. Electrostimulation + postural training (as described below) performed daily.	1- Cobb angle	At 6 months follow-up, the Cobb angle significantly (P<0.01) improved in the IG compared with the CG.
	CG: *n*=40 Loss to follow-up=0 15.0 (4.0) years F: 43 (54%) M: 37 (46%)	S-shaped scoliosis excluding C-shaped scoliosis. Mean Cobb angles: 25º (13) and 23º (11), respectively.	Control: electrostimulation + postural training + traction. First day: electrostimulation on the lateral curvature for 3x/day for 30 minutes each. Second day: electrostimulation for 2x/hour. Third day: electrostimulation for 1x/3 hours. 1 hour daily increase until 8 hours/day with progression to traction therapy for 30 minutes with postural training.		

Study	Sample	Type and size of spinal curves included in the study	Description of the intervention(s)	Outcomes	Results
Toledo 2011 [17]	IG: *n*=10 Loss to follow-up=0 10.0 (3.0) years F: 4 (40%) M: 6 (60%)	Structural thoracic scoliosis excluding patients without positive tests. Mean Cobb angle: 15.0º (10.0).	Intervention: global postural re-education for 25 to 30 minutes with 2 to 3 minutes of rest, 2x/week for 12 weeks.	1- Cobb angle	At 6 months follow-up, the Cobb angle improved significantly (*P*=0.009) in the IG compared with the CG.
	CG: *n*=10 Loss to follow-up=0 10.0 (3.0) years F: 5 (50%) M: 5 (50%)	Structural thoracic scoliosis excluding patients without positive tests. Mean Cobb angle: 14.0º (7.0).	Control: no treatment.		
Diab 2012 [16]	IG: *n*=38 Loss to follow-up=2 13.2 (1.2) years F: 18 (47%) M: 20 (53%)	All types of curves with Cobb angles of 10 to 30º and Risser sign of 0, 1 or 2. Lenke scale of 1A or sagittal thoracic curve of <+10.	Intervention: corrective exercise programme consisting of tailored forward head posture corrections + traditional stretching + strengthening exercises. Conventional treatment 3x/week + three sets of 12 repetitions of strengthening exercises, 4x daily, for 10 weeks. Stretching cervical flexors + unilateral and bilateral pectoralis alternating at 2-week period. Three stretching exercises held for 30 seconds each.	1- Craniovertebral angle 2 - Trunk inclination 3 - Lordosis 4 - Kyphosis 5 - Trunk imbalance 6 - Lateral deviation 7 - Pelvic torsion 8 - Surface rotation 9 - FRI	At 10 weeks, there were improvements in craniovertebral angle (*P*=0.006), trunk inclination (*P*=0.005), lordosis (*P*=0.01), kyphosis (*P*=0.001), trunk imbalance (*P*=0.001), lateral deviation (*P*=0.001), pelvic torsion (*P*=0.004) and surface rotation (*P*=0.013). At 3 months, significant (*P*<0.05) improvements in all outcome measures

Study	Sample	Type and size of spinal curves included in the study	Description of the intervention(s)	Outcomes	Results
	CG: *n*=38 Loss to follow-up=5 14.5 (1.3) years F: 17 (45%) M: 21 (55%)		Control: traditional exercise treatment – stretching of concave tightened structures + strengthening of trunk muscles 3x/week for 10 weeks.		were observed in the IG. At 10 weeks. there was no difference between groups in FRI. At 3 months, FRI was significantly (*P*<0.001) lower in the IG compared with the CG.
Monti-cone 2014 [18]	IG: *n*=55 Loss to follow-up=5 12.5 (1.1) years F: 39 (71%) M: 16 (29%)	All types of curves with Cobb angles of 10 to 25º and Risser sign <2. Mean Cobb angle: 19.3º (3.9).	Intervention: active self-correction + tailored exercises + cognitive-behavioural strategies + ergonomic education. 60 minutes of outpatient sessions delivered once a week + 30 minutes of home sessions 2x/week. Mean time on treatment=42.8 months (SD 9.1).	1 - Cobb angle 2 - ATR 3 - SRS-22 function 4 - SRS-22 pain 5 - SRS-22 self-perceived image 6 - SRS-22 mental health 7 - SRS-22 self-satisfaction	Mean change in the Cobb angle showed significant (*P*<0.001) improvement in the IG at skeletal maturity. There was a decrease in ATR in the IG post-training. The IG showed significant (*P*<0.001) improvements in all domains of the SRS-22 score at skeletal maturity.
	CG: *n*=55 Loss to follow-up=7 12.4 (1.1) years F: 41 (75%) M: 14 (25%)	All types of curves with Cobb angles of 10 to 25º and Risser sign <2. Mean Cobb angle: 19.2º (2.5).	Control: general exercises for spinal mobilisation. 60 minutes of outpatient sessions. Once a week + 30 minutes of home programme sessions 2x/week at home.		
Schreiber 2015 [15]/ 2016 [14]	IG: *n*=25 Loss to follow-up=4 13.5 (12.7 to 14.2) years F: 23 (92%)	All types of curves with Cobb angles of 10 to 45° and Risser sign of 0 to 5 (all skeletal maturities). Mean Cobb angle: 48.1º (39.1 to 57.2).	Intervention: active self-correction + tailored exercises + bracing if criteria were met + ergonomic education. 5x 60 minutes of outpatient sessions delivered first 2 weeks, then 60 minutes 1x/week + 30 to 45 minutes of daily home sessions for 6 months.	1 - (SRS-22r function)[4] 2 - (SRS-22r pain)[4] 3 - (SRS-22r self-image)[4] 4 - (SRS-22r total)[4]	No difference (*P*=0.45) between groups for pain at 3 months; improvements (*P*=0.03) were observed at 6 months in favour of the IG. At 3 months, self-image seemed better (*P*=0.14) for the CG, but at 6 months,

Study	Sample	Type and size of spinal curves included in the study	Description of the intervention(s)	Outcomes	Results
	M: 2 (8%)			5 - BME endurance 6 - SAQ 7 - SEQ 8 - Cobb angle	significant (*P*=0.049) improvements were observed in the IG. At 3 months, the IG showed a significant difference (*P*=0.04) in the BME endurance test from the CG, but no difference was seen at 6 months. No difference was reported for SRS-22r total, SAQ and SEQ scores.
	CG: *n*=25 Loss to follow-up=2 13.3 (12.7 to 13.9) years F: 24 (96%) M: 1 (4%)	All types of curves 10–45°. Risser 0–5 (all skeletal maturities). Mean Cobb angle: 54.3º (44.9 to 63.6).	Control: standard care, consisting of observation or bracing if the SRS bracing criteria were met.		

Study	Sample	Type and size of spinal curves included in the study	Description of the intervention(s)	Outcomes	Results
					Significantly (P=0.006) smaller largest curve was reported for the IG compared with the CG. This difference was associated with increased weight and higher severity classifications. At 6 months, the √sum of curves improved by 0.4° (P=0.048) in the IG compared with the CG. This difference between groups increased with curve severity.
Kim 2016 [20]	IG: n=12 Loss to follow-up=0 15.6 (1.1) years F: 12 (100%) M: 0 (0%)	Curve types not specified. Mean Cobb angle: 23.6° (1.5).	Intervention: Schroth + three-dimensional rotational breathing: 60 minutes, 3x/week for 12 weeks.	1 - Cobb angle 2 - Weight distribution	Cobb angle showed significant (P<0.05) between- and within-group differences for both groups, but higher improvements were reported for the IG at 12 weeks. No within-group difference was noted for weight distribution in the CG, but the IG showed significant (P<0.05) improvement in weight distribution.
	CG: n=12 Loss to follow-up=0 15.3 (0.8) years F: 12 (100%) M: 0 (0%)	Curve types not specified. Mean Cobb angle: 24.0° (2.6).	Control: 60 minutes of Pilates exercise applied along with trunk breathing, 3x/week for 12 weeks.		

Study	Sample	Type and size of spinal curves included in the study	Description of the intervention(s)	Outcomes	Results
Kuru 2016 [9]	IG1: *n*=15 Loss to follow-up=0 12.9 (1.4) years F: 14 (93.3%) M: 1 (6.7%)	Cobb angle: 10 to 60°. Risser sign: 1.5 (1.3). Mean Cobb angle: 33.4° (8.9).	Intervention: supervised Schroth + asymmetric position rotational breathing: 1.5 hours/day, 60 minutes, 3x/week for 6 weeks + home programme.	1 - Cobb angle 2 - ATR 3 - Height of gibbosity 4 - Waist asymmetry 5 - SRS-23 total score	At 24 weeks, greater improvements in Cobb angle (*P*=0.0003), ATR (*P*=0.000), height of hump (*P*=0.000) and waist asymmetry (*P*=0.000) were observed in the supervised exercise group compared with the home exercise group and the CG.
	IG2: *n*=15 13.1 (1.7) years F: 12 (86.7%) M: 3 (20.0%)	Cobb angle: 10–60°. Risser sign: 1.4 (1.4). Mean Cobb angle: 30.3° (7.6).	Intervention: home programme Schroth + asymmetric position rotational breathing, 18 sessions for 6 weeks.		
	CG: *n*=15 12.8 (1.2) years F: 13 (80%) M: 2 (20%)	Cobb angle: 10 to 60°. Risser sign: 1.0 (1.2). Mean Cobb angle: 30.3° (6.6).	Control: observation only.		
Gur 2017 [19]	IG: *n*=12 Loss to follow-up=0 14.2 (1.8) years F: 11 (91.6%) M: 1 (8.3%)	Curve types not specified. Risser sign: 2 (0.6). Mean Cobb angle: thoracic 35º (11.82) lumbar 29º (8.35) total 56.75º (25.70)	Intervention: core stabilisation exercises + traditional treatment (exercise training + breathing + bracing) + diaphragmatic breathing. 20 sessions, 60 minutes each, 2x/week, for 10 weeks + daily home programme.	1 - Cobb angle thoracic 2 - Cobb angle lumbar 3 - AVR 4 - AVR thoracic 5 - AVR lumbar 6 - POTSI	Greater improvements in lumbar rotation and the pain domain of the SRS-22 (*P*<0.05) in the IG compared with the CG. No significant between-group differences for Cobb angle, trunk asymmetry, cosmetic trunk deformity, quality of life and measures of compliance.

Study	Sample	Type and size of spinal curves included in the study	Description of the intervention(s)	Outcomes	Results
	CG: *n*=13 Loss to follow-up=0 14 (1.6) years F: 13 (100.0%) M: 0	Curve types not specified. Risser sign: 2 (0.6). Mean Cobb angle: thoracic 31.42º (6.97) lumbar 34.33º (9.2) total 60.69º (17.75)	Control: traditional treatment which included exercise training + breathing + bracing. 20 sessions, 60 minutes each, 2x/week, for 10 weeks + daily home programme.	7 - TAPS 8 - SRS-22 pain 9 - SRS-22 self-image 10 - SRS-22 function 11 - SRS-22 mental health 12 - SRS-22 total 13 - Brace compliance 14 - Exercise compliance	However, an average reduction of 9° and 2° in total Cobb angle was reported for the IG and CG, respectively.
Zheng 2017 [22]	IG: *n*=30 Loss to follow-up=1 12.4 (0.9) years F: 22 (76.0%) M: 7 (24.0%)	Cobb angle: ≥20 to 40º. Risser sign: 0, 1 or 2. Mean Cobb angle: 27.0º (3.6).	Intervention: scientific exercise approach to scoliosis + traditional treatment + diaphragmatic breathing. Single 1.5-hour session every 2 to 3 months + clinic treatment, 1x/week, for 10 weeks + daily home programme (10 to 15 minutes).	1 - Cobb angle thoracic 2 - Correction of Cobb angle 3 - ATI degree 4 - SRS-22 function 5 - SRS-22 pain 6 - SRS-22 self-image 7 - SRS-22 mental health 8 - SRS-22 Self-	The bracing group achieved significant improvement in measures of spinal curvature. Cobb angle (22.1 ± 4.8 vs 24.8±4.4) at 12 months of evaluation (*P*=0.039). Correction of Cobb angle at 6 months (*P*=0.005) and 12 months (*P*=0.01) compared with the exercise group. The exercise group showed higher improvement at 6 and 12 months for function, mental health and total SRS scores compared with the bracing group.
	CG: *n*=30 Loss to follow-up=6 12.3 (0.8) years F: 19 (79.2%)	Cobb angle: ≥20 to 40º. Risser sign: 0, 1 or 2. Mean Cobb angle: 28.0º (3.6).	Control: brace - rigid thoraco-lumbosacral orthosis worn for 23 hours/day. Checking and modification 1 month after prescription and then reviewed every 3 months/year.		

Study	Sample	Type and size of spinal curves included in the study	Description of the intervention(s)	Outcomes	Results
	M: 5 (20.8%)			satisfaction 9 - SRS-22 total score 10 - Brace and exercise compliance	SRS subscales of self-image (*P*=0.004) and self-satisfaction (*P*=0.006) showed improvement in the exercise group at 6 months alone. No effect was demonstrated on SRS pain for either group.

IG, intervention group; F, female, M, male; SSE, scoliosis-specific exercises; x, times; s, seconds; CG, control group; FRI, Functional Rating Index; ATR, angle of trunk rotation; SRS-22, Scoliosis Research Society; BME, Biering-Sorensen Muscle Endurance Test; SAQ, Spinal Appearance Questionnaire scores; SEQ, Self-efficacy Questionnaire; AVR, apical vertebral rotation; TAPS, Trunk Appearance Perception Scale; POTSI, Posterior Trunk Symmetry Index.

Table 2
Risk of bias ratings for randomised studies

Wan 2005 [21]	Toledo 2011 [17]	Diab 2012 [16]	Monticone 2014 [18]	Schreiber 2015 [15]	Kim 2016 [20]	Kuru 2016 [9]	Gur 2017 [19]	Zheng 2017 [22]	Trial characteristics	Classification	
										✖	High risk of bias
										?	Unclear
										✓	Low risk of bias
?	?	✓	✓	✓	?	✓	?	✓	Random sequence generation (selection bias)		
?	?	✓	✓	✓	?	?	?	✓	Allocation concealment		
✖	✖	✖	✖	✖	✖	✖	?	✖	Blinding (performance bias and detection bias): patients		
✖	✖	✖	✖	✖	✖	✖	?	✖	Blinding (performance bias and detection bias): clinicians		
✖	✖	✖	✓	✓	?	?	?	?	Blinding (performance bias and detection bias): outcome assessors		
✓	✓	✓	✓	✓	✓	✓	✓	✓	Incomplete outcome data (attrition bias): were dropouts reported and equal between groups?		
✓	✓	✓	✓	✓	✓	✓	✓	✓	Incomplete outcome data (attrition bias): were all randomised participants analysed in the group to which they were allocated?		
✓	✓	✓	✓	✓	✓	✓	✓	✓	Selective reporting (reporting bias)		
✓	✓	✓	✓	✓	✓	?	?	✓	Groups similar at baseline		
?	?	?	?	✓	?	?	✓	✓	Co-interventions		
?	?	?	?	✓	?	?	?	?	Adherence with interventions		
✓	✓	✓	✓	✓	?	✓	✓	✓	Similar outcome timing		
High	High	Unclear	Low	Low	High	Unclear	High	Unclear	Overall risk of bias		

Table 3a

Cobb angle

Outcome	Arm\Study	Wan 2005 [21]	Toledo 2011 [17]	Monticone 2014 [18]	Kim 2016 [20]	Kuru 2016 [9]	Schreiber 2016 [14]	Gur 2017 [19]	Zheng 2017 [22]
Cobb angle (°) - [mean (SD)/median (min to max)]	SSE	*Thoracic spine* 0 weeks: 26.0 (12.0) 6 months: 10.0 (7.0)** *Lumbar spine* 0 weeks: 24.0 (10.0) 6 months: 9.0	0 months: 15.1 (2.5) 6 months: 9.8 (2.9)**	0 months: 19.3 (3.9) 42 months: 14.0 (2.4)** 56 months: 14.3 (2.3)**	0 months: 23.6 (1.5) 3 months: 12.0 (4.7)*	*Supervised SSE* 0 months: 32.0 (20.0 to 50.0) 6 months: 32.0 (22.0 to 45.0) *Home programme SSE* 0 months: 30.0 (20.0 to 40.0) 6 months: 35.0 (20.0	0 months: 29.1 (8.9) 6 months: 27.7 (8.9)	*Thoracic spine* 0 weeks: 35.0 (11.8) 10 weeks: 28.5 (11.9) *Lumbar spine* 0 weeks: 29.0 (8.4) 10 weeks: 23.6 (10.4)	*Cobb angle* 0 months: 27.0 (3.6) 6 months: 25.5 (3.6) 12 months: 24.8 (4.4)

		(5.0)**				to 45.0)		*Total* 0 weeks: 56.8 (25.7) 10 weeks: 45.6 (54.4)	
	Control	*Thoracic spine* 0 weeks: 25.0 (13.0)	0 months: 14.7 (3.8)	0 months: 19.2 (2.5)	0 months: 28.0 (20.0 to 45.0)	0 months: 28.0 (20.0 to 45.0)	0 months: 27.9 (8.8)	*Thoracic spine* 0 weeks: 31.4 (7.0)	*Cobb angle* 0 months: 28.0 (3.6)
		6 months: 18.0 (9.0)**	6 months: 16.1 (3.8)**	42 months: 20.9 (2.2)**	6 months: 32.0 (22.0 to 46.0)	6 months: 32.0 (22.0 to 46.0)	6 months: 29.1 (8.8)	10 weeks: 33.9 (7.3)	6 months: 25.3 (3.6)
		Lumbar spine 0 weeks: 23.0 (11.0)		56 months: 22.0 (1.6)**				*Lumbar spine* 0 weeks: 34.3 (9.2)	12 months: 22.1 (4.8)
		6 months:16.0 (8.0)**						10 weeks: 32.6 (10.2)	

								Total 0 weeks: 60.7 (17.8) 10 weeks: 59.1 (20.0)	

Min, minimum; max, maximum; SSE, scoliosis-specific exercises.

[a]Significant difference from pre-test.

*P<0.05; **P<0.001.

Table 3b

Other measures of Cobb angle outcome measures

Study	Outcome	Time point	SSE		Control	
Monticone 2014 [18]	Stratified by age: Cobb angle, mean (SD)	Baseline	Age <13 years (*n*=32) 18.9 (4.1)	Age >13 years (*n*=23) 19.9 (3.6)	Age <13 years (*n*=35) 19.3 (2.4)	Age >13 years (*n*=20) 19 (2.7)
		42 months	14.1 (2.5)**	14.0 (2.4)**	20.7 (2.5)**	21.4 (1.8)**
		56 months	14.2 (2.3)**	14.5 (2.4)**	21.9 (1.6)**	22.1 (1.5)**
	Participants whose Cobb angle changed by >3° by age group, *n* (%)	Post assessment	Improved 22/31 (71%)	14/21(66.7%)	3/32 (9.4%)	0/19 (0%)
			Same 6/31 (19.3%)	6/21 (19.3%)	19/32 (59.4%)	9/19 (59.4%)
			Worsened 3/31 (9.7%)	1/21 (4.8%)	10/32 (31.2%)	10/19 (31.2%)
	Participants whose Cobb angle changed by >3° overall, *n* (%)	Post assessment	Improved 36/52 (69%)		3/51 (6%)	
			Same 12/52 (23%)		28/51 (55%)	
			Worsened 4/52 (8%)		20/51 (39%)	
Zheng 2017 [22]	Correction of Cobb angle (°), mean (SD)	Baseline	1.6 (1.5)		2.8 (4.7)	
		6 months	0.7 (2.6)		3.1 (3.7)	
		12 months	2.2 (3.2)		5.9 (6.4)	

SD, standard deviation.

Table 3c

Measures of spinal rotation

Study	Outcome	Time point	Scoliosis-specific exercises		Control
			Supervised SSE1	Home programme SSE2	Observation
Kuru 2017 [9]	ATR (°), mean (SD)	Baseline	11.9 (5.2)**	9.6 (4.5)	8.4 (2.9)
		6 weeks	7.4 (4.7)	10.2 (5.1)	9.2 (3.0)
		12 weeks	7.6 (5.0)	10.5 (5.3)	9.8 (3.2)
		24 weeks	7.7 (5.2)**	11.7 (5.9)	10.5 (4.2)
Gur 2017 [19]	Rotation AVR, thoracic (°), mean (SD)	Baseline	11.8 (5.2)		9.0 (5.2)
		10 weeks	9.5 (5.6)		8.1 (4.2)
	Rotation AVR, lumbar (°), mean (SD)	Baseline	7.7 (3.0)		12.1 (6.4)
		10 weeks	3.8 (3.2)*		8.2 (4.8)
	Rotation AVR, total (°), mean (SD)	Baseline	17.5 (6.9)		19.3 (6.9)
		10 weeks	12.3 (6.3)		15.0 (6.0)
Zheng 2017 [22]	Angle of trunk inclination (°), mean (SD)	Baseline	8.6 (2.2)		9.6 (2.2)
		6 months	8.0 (1.5)		8.3 (1.1)
		12 months	7.3 (1.4)		7.5 (1.0)

ATR, angle of trunk rotation; AVR, apical vertebral rotation; SD, standard deviation.

Table 4 Scoliosis Research Society-22 Questionnaire (SRS-22) patient-reported secondary outcome measures

		Monticone 2014 [18]			Schreiber 2015 † [15]			Gur 2017 [19]		Kuru 2017 [9]				Zheng 2017 [22]		
Outcome [mean (SD)]	Arm\Time point	0 months	42 months	56 months	0 months	3 months	6 months	0 weeks	10 weeks	0 weeks	6 weeks	12 weeks	24 weeks	0 months	6 months	12 months
SRS-22 function	SSE	3.8 (0.5)	4.7 (0.2)***	4.8 (0.2)***	444.5 (46.8)†	442.8 (47.4)†	485.3 (48.5)†	4.5 (0.4)	4.7 (0.4)	-	-	-	-	4.6 (0.2)	4.9 (0.2)***	4.9 (0.1)***
	Control	3.9 (0.5)	4.0 (0.4)***	3.9 (0.4)***	413.6 (49.3)†	395.9 (50.4)†	408.3 (50.7)†	4.4 (0.5)	4.6 (0.4)	-	-	-	-	4.5 (0.2)	4.6 (0.2)	4.7 (0.1)
SRS-22 pain	SSE	3.8 (0.4)	4.6 (0.3)***	4.7 (0.2)***	422.8 (31.5)†	460.8 (32.4)†	526.0 (33.4)†	4.5 (0.4)	4.7 (0.4)*	-	-	-	-	4.8 (0.1)	5.0 (0.1)	4.9 (0.1)
	Control	9.0 (0.5)	4.3 (0.3)	4.2 (0.4)	348.6 (31.4)†	415.7 (32.6)†	395.7 (32.4)†	4.1 (0.5)	4.0 (0.5)	-	-	-	-	4.9 (0.1)	4.9 (0.1)	4.9 (0.1)
SRS-22 self-image	SSE	3.6 (0.6)	4.4 (0.3)***	4.6 (0.3)***	4.0 (0.12)	3.9 (0.1)	4.0 (0.1)	3.6 (0.6)	3.7 (0.6)	-	-	-	-	3.5 (0.3)	4.0 (0.2)**	4.4 (0.2)
	Control	3.4 (0.6)	3.7 (0.5)***	3.6 (0.4)***	3.9 (0.12)	4.0 (0.1)	3.8 (0.1)	3.7 (0.6)	3.6 (0.7)	-	-	-	-	3.5 (0.5)	3.8 (0.3)**	4.3 (0.3)
SRS-22 mental health	SSE	3.8 (0.6)	4.5 (0.3)***	4.7 (0.2)***	-	-	-	3.4 (1.1)	3.56 (1.0)	-	-	-	-	4.1 (0.2)	4.3 (0.3)***	4.5 (0.2)***
	Control	3.9 (0.6)	3.9 (0.5)***	3.8 (0.4)***	-	-	-	3.8 (0.7)	3.9 (0.8)	-	-	-	-	4.1 (0.2)	3.9 (0.19)	4.2

															(0.3)
SRS-22 satisfaction with management	SSE	NA	4.8 (0.3)***	4.9 (0.3)***	-	-	-	-	-	-	-	-	-	3.8 (0.3)	4.0 (0.4)**	4.4 (0.5)
	Control	NA	4.0 (0.5)***	4.2 (0.5)***	-	-	-	-	-	-	-	-	-	3.7 (0.3)	3.5 (0.7)	4.1 (0.8)
SRS 22r / 23 total	SSE	-	-	-	4.3 (0.1)	4.3 (0.1)	4.4 (0.1)	4.0 (0.5)	4.3 (0.4)	*Convex* 4.2 (2.7 to 4.7) *Concave* 4.0 (3.2 to 4.5)	*Convex* 4.2 (3.3 to 4.7) *Concave* 4.0 (3.3 to 4.7)	*Convex* 4.3 (3.3 to 4.8) *Concave* 4.1 (3.5 to 4.8)	*Convex* 4.4 (3.5 to 5.0) *Concave* 3.9 (3.9 to 4.7)	92.6 (2.1)	98.6 (2.3)***	102.2 (1.9)***
	Control	-	-	-	4.2 (0.1)	4.2 (0.1)	4.2 (0.1)	4.0 (0.5)	4.0 (0.5)	4.1 (3.3 to 4.6)	4.2 (3.3 to 4.6)	4.0 (3.5 to 4.7)	4.1 (3.0 to 4.7)	92.7 (4.1)	92.9 (2.5)	99.0 (2.3)

SSE, scoliosis-specific exercises; SD, standard deviation; NA, not available.

*P<0.05; **P<0.01; ***P<0.001.

†Schreiber – data reported were transformed to the power of 4.

Table 5

Other relevant secondary outcome measures

Study	Outcome	Time point	Scoliosis-specific exercises	Control
Diab 2012 [16]	Functional rating index [mean (SD)]	Baseline 10 weeks 3 months	13.9 (1.7) 10.7 (0.9) 10.0 (0.9)*	16.1 (1.7) 11.9 (2.0) 13.8 (1.9)*
Gur 2017 [19]	TAPS [mean (SD)]	Baseline 10 weeks	3.0 (0.5) 3.5 (0.5)	2.8 (0.6) 3.5 (0.6)
	POTSI [mean (SD)]	Baseline 10 weeks	29.8 (11.1) 32.4 (12.3)	21.9 (9.2) 27.1 (16.7)
	Treatment compliance (brace) [mean (SD)]	10 weeks	88.1 (15.1)	88.8 (13.0)
	Treatment compliance (exercise) [mean (SD)]	10 weeks	82.3 (15.3)	86.9 (9.9)

Study	Outcome	Time point	Scoliosis-specific exercises	Control
Schreiber 2015 [14]	SAQ general [mean (SD)]	Baseline 10 weeks 3 months	2.7 (0.2) 2.8 (0.2) 2.6 (0.2)	2.6 (0.2) 2.4 (0.2) 2.4 (0.2)
	Treatment compliance (supervised exercise) (%)	3 months	76%	NA
	Treatment compliance (home exercises) (%)		73%	NA
Zheng 2017 [22]	Treatment compliance [mean (SD)]	12 months	59.1 (0.2)	57 (0.3)

SD, standard deviation; TAPS , Trunk Appearance Perception Scale; POTSI, Posterior Trunk Symmetry Index; SAQ, Spinal Appearance Questionnaire; NA, not applicable .

*P<0.05; **P<0.001.

Table 6a

Summary of findings table – GRADE levels of evidence for studies comparing scoliosis-specific exercises with standard care

Outcome	Participants	Design (studies)	RoB	Inconsistency	Indirectness	Imprecision	Certainty
Cobb angle	401	7 RCTs	High	Good	Poor	Good	Very low
Overall improvement in Cobb angle	110	1 RCT	Low	NA	Good	Poor	Low‡
Angle of trunk rotation	143	3 RCTs	High	Poor	Poor	Poor	Very low
SRS-22/SRS-23 total scores	128	3 RCTs	High	Good	Poor	Poor	Very low
Functional ability	242	4 RCTs	High	Poor	Poor	Poor	Very low†
Pain	173	3 RCTs	High	Good	Poor	Poor	Very low†
Self-image	167	3 RCTs	High	Poor	Poor	Poor	Very low

Mental health	123	2 RCTs	High	NA	Poor	Poor	Very low
Satisfaction with management	110	1 RCT	Low	NA	Good	Poor	Low*
Adverse events	110	1 RCT	Low	NA			
Cost-effectiveness	Not measured	-	-	-	-	-	No evidence
Rate of surgery or brace prescription due to curve progression	Not measured	-	-	-	-	-	No evidence

RoB , risk of bias; RCT, randomised controlled trial; NA, not applicable; SRS, Scoliosis Research Society Questionnaire.

*Downgraded for being a single study.

† Downgraded because results presented by one study were transformed to the power of 4 (function^4 and pain^4) and it was not possible to combine the data.

Table 6b

Summary of findings table – GRADE levels of evidence comparing scoliosis-specific exercises with standard care

Outcome	Participants	Design (studies)	RoB	Inconsistency	Indirectness	Imprecision	Certainty

Cobb angle	53	1 RCT	Unclear	NA	Good	Poor	Very low*
Angle of trunk rotation	53	1 RCT	Unclear	NA	Good	Poor	Very low*
SRS-22 total score	53	1 RCT	Unclear	NA	Good	Poor	Very low*
Functional ability	53	1 RCT	Unclear	NA	Good	Poor	Very low*
Pain	53	1 RCT	Unclear	NA	Good	Poor	Very low*
Self-image	53	1 RCT	Unclear	NA	Good	Poor	Very low*
Mental health	53	1 RCT	Unclear	NA	Good	Poor	Very low*
Satisfaction with management	53	1 RCT	Unclear	NA	Good	Poor	Very low*
Compliance	53	1 RCT	Unclear	NA	Good	Poor	Very

							low*
Adverse events	Not measured	-	-	-	-	-	No evidence
Rate of surgery or brace prescription due to curve progression	Not measured	-	-	-	-	-	No evidence

RoB, risk of bias; RCT, randomised controlled trial; NA, not applicable; SRS-22, Scoliosis Research Society-22 Questionnaire.

*****Results from one study with strict bracing criteria (23 hours/day for 12 months); downgraded for being a single study.