

Exercises for Adolescent Idiopathic Scoliosis

A Cochrane Systematic Review

Michele Romano, PT,* Silvia Minozzi, MD,† Fabio Zaina, MD,* Josette Bettany Saltikov, PhD,‡ Nachiappan Chockalingam, PhD,§ Tomasz Kotwicki, MD, PhD,¶ Axel Maier Hennes, PT,|| and Stefano Negrini, MD**

Study Design. Systematic review of interventions.

Objective. To evaluate the efficacy of scoliosis-specific exercise (SSE) in adolescent patients with adolescent idiopathic scoliosis (AIS).

Summary of Background Data. AIS is a 3-dimensional deformity of the spine. Although AIS can progress during growth and cause a surface deformity, it is usually not symptomatic. However, in adulthood, if the final spinal curvature surpasses a certain critical threshold, the risk of health problems and curve progression is increased. The use of SSEs to reduce progression of AIS and postpone or avoid other more invasive treatments is controversial.

Methods. Search methods: The following databases (up to March 30, 2011) were searched with no language limitations: CENTRAL (The Cochrane Library 2011, issue 2), MEDLINE (from January 1966), EMBASE (from January 1980), CINHAL (from January 1982), SPORTDiscus (from January 1975), PsycINFO (from January 1887), and PEDro (from January 1929). We screened reference lists of articles and conducted an extensive hand search of gray literature. Selection criteria: randomized controlled trials and prospective cohort studies with a control group comparing exercises with no treatment, other treatment, surgery, and different types of exercises. Data collection and analysis: Two review authors independently selected studies, assessed risk of bias and extracted data.

Results. Two studies (154 participants) were included. There is low-quality evidence from 1 randomized controlled study that exercises as an adjunctive to other conservative treatments to increase the efficacy of these treatments (thoracic curve reduced:

mean difference 9.00, [95% confidence interval, 5.47–12.53]; lumbar curve reduced: mean difference 8.00, [95% confidence interval, 5.08–10.92]). There is very low-quality evidence from a prospective controlled cohort study that SSEs structured within an exercise program can reduce brace prescription (risk ratio, 0.24; [95% confidence interval, 0.06–1.04]) as compared with “usual physiotherapy” [many different kinds of general exercises according to the preferences of the single therapists within different facilities]).

Conclusion. There is a lack of high-quality evidence to recommend the use of SSE for AIS. One very low-quality study suggested that these exercises may be more effective than electrostimulation, traction, and postural training to avoid scoliosis progression, but better quality research needs to be conducted before the use of SSE can be recommended in clinical practice.

Key words: adolescent idiopathic scoliosis, AIS, scoliosis, scoliosis-specific exercises, exercise, Cochrane review, systematic review, back pain, quality of life, conservative treatment.

Level of Evidence: 2

Spine 2013;38:E883–E893

Scoliosis is a complex deformity of the spine that develops in 3-dimensions and results in the appearance of frontal curves, fixed vertebral rotations, and a flattening of the sagittal physiological curves. When scoliosis develops between 10 years of age and the end stage of growth, it is called adolescent idiopathic scoliosis (AIS); idiopathic meaning that there is no known cause. A curvature in the spine can develop at any level of the spine and depending on the vertebrae that are affected, is referred to as either a thoracic, thoracolumbar, or lumbar scoliosis. Although scoliosis can be secondary to other pathologies, in 70% to 80% of cases, the causes are unknown.¹ AIS is the most common diagnosis. The magnitude of scoliotic curves in the frontal plane is generally measured on radiographs and is referred to as the Cobb angle,² named after the spinal surgeon who devised the method. The Cobb angle is the angle that measures the curvature of the spine in the frontal plane and measures the angle that includes all of the deformed vertebrae. It is generally agreed that curves that measure up to 25° Cobb are classed as mild curves; whereas moderate curves are considered to be those measuring from 25° to 45° Cobb and severe curves measure more than 45° Cobb angle. If scoliosis surpasses a critical threshold, usually considered to be 30° Cobb, at the end stage of growth, the risk

From the *ISICO (Italian Scientific Spine Institute), Milan, Italy; †Department of Epidemiology, Lazio Regional Health Service, Rome, Italy; ‡School of Health and Social Care, University of Teeside, Middlesbrough, UK; §Faculty of Health, Staffordshire University, Stoke on Trent, UK; ¶Department of Pediatric Orthopedics and Traumatology, University of Medical Sciences, Poznan, Poland; ||Scoliosis Rehabilitation Centre, Bad Sobernheim, Germany; and **Physical and Rehabilitation Medicine, University of Brescia - Don Gnocchi Foundation Milan, Brescia, Italy.

Acknowledgment date: March 27, 2013. Acceptance date: March 27, 2013.

The manuscript submitted does not contain information about medical device(s)/drug(s).

No funds were received in support of this work.

Relevant financial activities outside the submitted work: stocks.

Address correspondence and reprint requests to Michele Romano, PT, ISICO (Italian Scientific Spine Institute), Via Roberto Bellarmino 13/1, 20141 Milan, Italy; E-mail: michele.romano@isico.it

DOI: 10.1097/BRS.0b013e31829459f8

of health problems in adulthood increases significantly.³ Problems include a decrease in the quality of life (QoL), disability, pain, increasing cosmetic deformity, functional limitations, sometimes pulmonary problems and possible progression during adulthood.⁴ The Cobb angle is a measurement on the frontal plane only. Even if attempts have been made to have a more 3-dimensional (3D) evaluation,⁵ today the “gold standard” remains the Cobb angle. To overcome this limitation, at the start and end of treatment, a complete radiographical evaluation is usually made, involving the assessment of spinal misalignment in the sagittal plane (the magnitude of lumbar lordosis and thoracic kyphosis are usually smaller than the physiological values).⁵

On the horizontal plane, the measurement of vertebral torsion is carried out with the Perdiolle torsionmeter⁶ or the Raimondi torsionmeter.⁷ Depending on the age of the individual at diagnosis, scoliosis evolves differently. According to the Scoliosis Research Society (SRS), the prevalence of AIS is 2% to 3% in the general population, almost 10% of whom require some form of treatment and up to 0.1% of whom will require surgery.³ AIS is more commonly found in females (female:male ratio is around 7:1). Except for extreme cases, AIS does not typically cause any health problems during growth; however, the resulting surface deformity frequently has a negative impact on adolescents that can give rise to QoL issues and in the worst cases, psychological disturbances.⁸

DESCRIPTION OF THE INTERVENTION

Because of the progressive nature of the deformity, adolescent patients are generally treated when the curvature is diagnosed. Furthermore, once the curve progresses, there are no treatments that succeed in fully correcting the spine. Depending on the mobility of the spine, reduction of the deformity can be difficult. The main treatment options for the prevention of scoliosis progression include scoliosis-specific exercises (SSE) and other forms of physical therapy, bracing, and surgery.⁹ The use of exercise for the treatment of AIS is controversial. Although it is routinely used in France, Germany, Italy, and a number of other countries in continental Europe, most centers in the United Kingdom and the United States do not advocate its use. Most clinicians (both physiotherapists and surgeons) in the United Kingdom and the United States do not normally appreciate the difference between SSE and general physiotherapy (GPT). SSEs consist of individually adapted exercises that are taught to the patients in a center that is dedicated to scoliosis treatment. The patients learn an exercise protocol that is personalized according to medical and physiotherapeutic evaluations. SSEs include a series of specific physical movements performed with a therapeutic aim of reducing the deformity. Exercises work mechanically by changing the musculature and other soft tissues of the spine. It is also thought that SSE can alter the motor control of the spine by affecting neurological changes that interact with each other.¹⁰ On the other hand, GPT is more generic, usually consisting of low-impact stretching and strengthening activities like Yoga, Pilates, or Tai chi (taiji), but can include different exercise protocols according to the preferences of the

therapist. The understanding within the generalized AIS treating community in the United Kingdom and the United States may be based on the effectiveness of GPT, which has not been shown to be effective.⁵

The overall aim of SSE is to reduce the progression of the scoliotic deformity and the postponement and possible avoidance of brace prescription. Negrini *et al*¹¹ and Ducongé¹² reported that SSE can stabilize and reduce curve magnitude as well as improve respiratory function that may be altered by chest deformity. Exercise has also been reported to reduce the incidence of surgery.¹³

HOW THE INTERVENTION MIGHT WORK

Scoliosis-specific exercises can be used in 3 main clinical scenarios: (1) the sole use of exercise as the primary treatment of AIS for mild curves, (2) in conjunction with braces for moderate curves, and (3) during adulthood if the scoliosis curves exceed certain thresholds.

In the treatment of mild scoliosis of less than 25° Cobb, the first main clinical scenario is the use of intense 3D spine and rib cage-specific exercises to try and avoid the use of a brace. This critical Cobb angle is generally regarded as the threshold for brace prescription.^{3,14} In mild scoliosis cases where exercise is prescribed, SSE is predominantly used according to the recommendations made by the Study group on Scoliosis and Orthopaedic and Rehabilitative Treatment. The key objectives of physical exercise in mild cases of AIS are the stabilization of the spine combined with 3D auto correction of the spine, pelvis, and rib cage.

Several studies have also shown that bracing (which “binds” the thorax for continuous periods of time) tends to reduce the QoL of young patients.¹⁵ Therefore, SSE can help to improve patients’ QoL by maintaining the curve and rib hump for as long as possible, thus reducing the need for braces.

The second main clinical scenario for SSE use is in conjunction with brace treatment. In this case, the aims are to reduce the side effects of wearing a brace (muscle weakness, rigidity, flat back) and to improve the efficacy of internal brace pads.¹⁶ SSE can also be used before a brace is worn to reduce spinal stiffness and improve mobility, thus helping to achieve a better correction.¹⁷ Moreover, SSE can help avoid losing correction while wearing the brace.¹⁸

Finally, the third possible clinical scenario is during adulthood. If scoliosis exceeds certain thresholds, significant problems such as back pain, breathing dysfunction, contractures, and progressive deformity can develop. These impairments and consequent disability can be addressed through exercise.¹⁹

WHY IT IS IMPORTANT TO DO THIS REVIEW

A scoping literature search identified 3 systematic reviews on the topic, none of which followed the Cochrane methodology.^{9,20,21} Therefore, we examined evidence that was published in these reviews and followed a more rigorous methodology to answer our clinical question “Is scoliosis-specific exercise therapy effective in delaying the progression of, or reducing the speed at which the curve progresses?” Preventing the

progression of the disease means avoiding the need for bracing, surgery, or both. We did not include studies on bracing, because there is another review where this is covered.²² However, we considered all studies investigating the effects of SSEs added to bracing if compared with bracing alone.

OBJECTIVE

The primary aim of this review was to evaluate the efficacy of SSEs in the treatment of AIS.

MATERIALS AND METHODS

Criteria for Considering Studies for This Review

Types of Studies

Randomized controlled trials (RCTs), quasi-RCTs (QRCTs), and observational studies were included, because it was anticipated that very few RCTs would be identified.

Types of Participants

We included studies in which all patients were diagnosed as having AIS with at least a 10° Cobb angle, and were between the ages of 10 years and the end stage of bone growth (in female adolescents, this is approximately between the ages of 15 and 17 yr; in male adolescents, this usually occurs between 16 and 19 yr of age). The end stage of bone growth can be determined by the Risser sign, which quantifies the ossification of the iliac crest. Stage 4 indicates total ossification of the apophysis, while stage 5, indicates fusion of the apophysis to the iliac crest and the end stage of further growth. The Greulich-Pyle atlas calculates the maturity of bones by assessing radiographs of the left hand.

We excluded studies in which patients presented with any type of secondary scoliosis (congenital, neurological, metabolic, post-traumatic, *etc.*), diagnosed according to the SRS criteria.²³

Types of Interventions

Experimental Intervention

The experimental interventions in this review included all types of SSEs, which are considered to be “specific movements performed with a therapeutic aim of reducing the deformity.” Sports, active recreational activities, and GPT were not considered to be specific exercises for the treatment of scoliosis and studies including these types of activities were excluded.

Type of Comparison

Comparison interventions included no treatment; different types of SSEs, “usual physiotherapy,” doses or schedules of exercises; or other nonsurgical treatments (*e.g.*, braces, electrical stimulation, manual therapy).

Comparisons included exercises *versus* no treatment, exercises plus another treatment *versus* the other treatment, exercises *versus* other treatments, exercises *versus* usual physiotherapy, different exercises *versus* each other, or different doses/schedules of exercises *versus* each other.

Types of Outcome Measures

This is a review of the effect of exercise on a radiological observation rather than a clinical syndrome.

Primary Outcomes

Progression of scoliosis, as measured by the following indicators:

- Cobb angle in degrees (absolute values).
- Angle of trunk rotation (ATR) in degrees (absolute values).
- Number of patients who have progressed by more than 5° Cobb.
- Number of subjects for whom brace or surgery were prescribed.

Cosmetic issues, as measured by the following indicators:

- Objective surface measurements, including Bunnell degrees or other measurements with validated scales or questionnaires (such as the Walter Reed Visual Assessment Scale).
- Topographic measurements, for example, the integrated shape imaging system angles, Quantec, and Formetric.²⁴

QoL and disability, as measured by the following indicators:

- Specific validated questionnaires such as SRS-22,²⁵ SF-36 Bad Sobernheim Stress Questionnaire (BSSQ), Brace Questionnaire (BrQ).²⁶

Back pain, as measured by the following indicators:

- Visual analog scale or other validated measurement tools.
- Use of drugs.

Psychological issues, as measured by the following indicators:

- Specific questionnaires such as sub-scales of SRS-22 and SF-36, BrQ.

Secondary Outcomes

Adverse effects, as outlined in identified trials, were also reported.

All outcomes (primary and secondary) were measured in the very short term (any result before the end stage of bone growth), the short term (results at the end stage of bone growth), and long term (results in adulthood).

Search Methods for Identification of Studies

Electronic Searches

We searched the following electronic databases:

1. CENTRAL (The Cochrane Library to March 30, 2011), which includes the Cochrane Back Review Group Trials Register.

2. MEDLINE (1966 to March 30, 2011).
3. EMBASE (1980 to March 30, 2011).
4. CINAHL (1982 to March 30, 2011).
5. SportDISCUS (1975 to March 30, 2011).
6. PsycINFO (1887 to March 30, 2011).
7. PEDro (1929 to March 30, 2011).

The updated search strategy recommended by the Cochrane Back Review Group for RCTs was used. This was adapted for cohort studies.²⁷ The strategy includes medical subject headings and text words. These include methodological terms, disorder terms, and treatment terms, and are listed in full for MEDLINE, EMBASE, CINAHL, and the other databases searched. These searches were updated on July 17, 2012.

Searching Other Resources

The following strategies were also used:

1. Screening of the reference lists of all relevant articles.
2. Searching of the main electronic sources of ongoing trials (National Research Register, meta-Register of Controlled Trials; Clinical Trials).
3. Searching of the gray literature, including conference proceedings and doctoral theses.
4. Contacting investigators and authors in this field for information on unpublished or incomplete trials.

All searches included non-English language literature

Data Collection and Analysis

Selection of Studies

Two review authors (S.N. and M.R.) independently screened the search results by reading titles and abstracts. Potentially relevant studies were obtained in full text and independently assessed for inclusion by 2 review authors, who resolved any disagreement through discussion. A third review author was contacted if disagreements persisted.

Data Extraction and Management

A standardized data extraction form was prepared and used to extract data from the included articles. Data extracted included study design (RCT, QRCT, prospective controlled cohort study), study characteristics (country, recruitment modality, study funding, risk of bias), patient characteristics (number of participants, age, sex, severity of scoliosis at baseline), description of the experimental and comparison interventions, cointerventions, adverse effects, duration of follow-up, outcomes assessed, and results. Two review authors (S.M. and J.B.-S.) who were not involved in the conduct of the primary studies, independently extracted the data. The data extraction form was not piloted because only 2 studies were included and data extracted were checked for any discrepancies for both included studies. Any disagreement was discussed and a third review author (T.K.) was consulted if disagreements persisted. Key findings were

summarized in a narrative format and then assessed for inclusion in a meta-analysis where possible.

Assessment of Risk of Bias in Included Studies

The risk of bias for RCTs and QRCTs was assessed using the 12 criteria recommended by the Cochrane Back Review Group,²⁷ which are an expansion of the “risk of bias” criteria listed in *The Handbook of Systematic Reviews of Interventions*.²⁸ The Newcastle-Ottawa Scale²⁹ was used to assess the observational studies. The Newcastle-Ottawa Scale assesses 3 broad areas: selection bias, attrition bias, and detection bias. Two review authors (S.M. and J.B.-S.), who were not involved in the conduct of the primary studies, independently assessed the internal validity of the included studies. Any disagreement between the review authors was resolved by discussion; a third independent reviewer (N.C.) was consulted if disagreements persisted. Risk of bias assessment was not blinded to trial authors, institution, or journal because the review team was familiar with the literature.

The criteria recommended and defined by the Cochrane Back Review Group²⁷ were scored as “high,” “low,” or “unclear” and were reported in the risk of bias table. A trial with low risk of bias was defined as a trial that met, at a minimum, criteria A (randomization), B (allocation concealment), C5 (outcome assessor blinding) and any 2 of the other criteria. It is very unlikely that trials on the effectiveness of exercise treatments could be blinded for participants and health care personnel. Nevertheless, the trials could have a blinded assessment of outcomes. The risk of bias tables were amended so they could be used to report the assessment of RCTs, QRCTs, and observational studies.

Assessment of Clinical Relevance

Each trial was assessed by the review authors (M.R., S.N., and F.Z.) for its clinical relevance, using the 5 questions outlined by Shekelle *et al.*³⁰ All outcomes within each comparison were discussed. Clinical significance (Shekelle question 4) was defined as a 5° Cobb change, which is the reliability of radiographical examination and the international “gold standard” for minimally significant clinical change.

Measures of Treatment Effect

Dichotomous outcomes were analyzed by S.M. (who was not involved in the conduct of the primary studies), by calculating the risk ratio (RR) for each trial, with the uncertainty in each result being expressed by 95% confidence intervals (CI). Continuous outcomes were analyzed by calculating the mean difference or the standardized mean difference with 95% CI.

Assessment of Heterogeneity

A *P* value of the χ^2 test less than 0.05 indicates a significant statistical heterogeneity. Clinical heterogeneity was also assessed for all retrieved studies. We planned to pool data only if the data were appropriately homogeneous.

Data Synthesis

Meta-analysis was not performed because only one RCT and 2 prospective observational controlled trials were found, both of which reported on different aspects of the same study.

Despite the fact that there were insufficient data available to use quantitative analyses to summarize the data, we assessed the overall quality of the evidence for each primary outcome. To accomplish this, we used an adapted GRADE approach, as recommended by the Cochrane Back Review Group.²⁷ The quality of the evidence on a specific outcome is based on the performance against 6 factors: study design, risk of bias, consistency and directness of results, precision of the data, and nonbiased reporting of the results across all studies that measured that particular outcome. The quality started at high when RCTs with a low risk of bias provided results for the outcome and reduced by a level for each of the factors not met. For evidence that is provided by nonrandomized trials, the quality started at low and is either reduced, based on performance against the same factors listed earlier (without study design) or increased if the evidence shows strong evidence of association, strong evidence of dose-response or evidence that all plausible confounders would have reduced the effect.³¹

High-quality evidence: There are consistent findings among at least 2 RCTs with low risk of bias that are generalizable to the population in question. There were sufficient data, with narrow CIs. There are no known or suspected reporting biases. Consistency is defined as 75% or more of the studies with similar results. Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality evidence: One of the factors is not met. Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low-quality evidence: Two of the factors are not met. Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low-quality evidence: Three of the factors are not met. Any estimate of effect is very uncertain.

No evidence: No evidence from RCTs.

Subgroup Analysis and Investigation of Heterogeneity

We had planned a subgroup analysis to explore the effects of the following variables: age, bone age, Cobb degrees, and type of exercise in the case of significant statistical heterogeneity, but meta-analysis was not performed.

Comparison Between Primary and Secondary Analysis

Separate analyses were performed for randomized (primary analysis) and observational studies (secondary analysis). Results obtained from the 2 analyses were compared and contrasted. Results of observational studies were added to the GRADE analysis as part of the comparison.

Sensitivity Analysis

To incorporate the risk of bias assessment in the review process, stratification of intervention effects had initially been

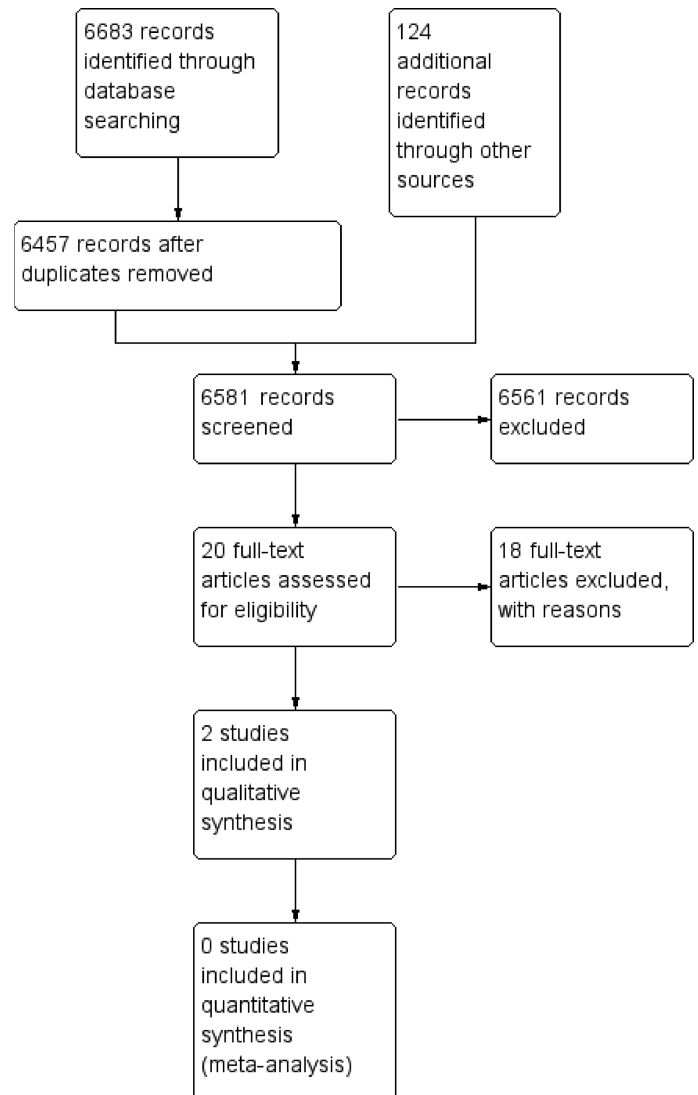


Figure 1. Study flow diagram.

planned. This would have included estimates by risk of bias as sensitivity analyses, excluding studies with high risk of bias from the analysis if differences in results were seen among studies at different risks of bias. As a meta-analysis was not performed, a risk of bias assessment could not be conducted.

RESULTS

Description of Studies

Results of the Search

With the bibliographical search, we identified 6807 references. After excluding duplicates, we identified 6581 potentially relevant references; 6561 were excluded on the basis of title and abstracts, leaving 20 studies that were acquired in full text for further evaluation (Figure 1).

Included Studies

We included 2 studies: one RCT³² and one prospective controlled cohort study.²¹

Characteristics of Included Studies

We included 2 studies: one RCT³² and one prospective controlled cohort study.²¹

The randomized trial by Wan *et al*,³² included 80 adolescents. Electrostimulation on the lateral body surface, traction therapy, and postural training and postural advice during normal activities were prescribed to both groups. The experimental group also performed SSE (Table 1).

The study by Negrini *et al*²¹ of 74 adolescents prescribed the SEAS (Scientific Exercise Approach to Scoliosis) exercises (a type of SSE), which consisted of an individual education session of scoliosis-specific SEAS exercises to be performed every 3 months. SSEs were then performed at home 2 to 3 times per week. The control group performed usual physiotherapy, which included exercise protocols according to the preferences of their single therapist (Table 2).

Excluded Studies

Eighteen studies were excluded for the following reasons: 12 studies were excluded because of the study design, 3 because of outcome measures, and 3 because of the type of intervention.

Risk of Bias in Included Studies

Overall, the risk of bias in the included studies was very high (Figure 2).

Allocation (Selection Bias)

Only one RCT was retrieved. The method used for random sequence generation and for concealment of allocation was not reported.

Blinding (Performance Bias and Detection Bias)

Neither the RCT nor the observational prospective study could be blinded for patients and providers because of the kind of intervention assessed (exercises). The outcome assessor was not blinded in either study.

Incomplete Outcome Data (Attrition Bias)

There were no dropouts from the RCT; in the study by Negrini *et al*²¹ the dropout rate was 6.7% and was balanced across groups; these results were included in a worst-case analysis.

Selective Reporting (Reporting Bias)

All studies seemed to be free of selective reporting.

Other Potential Sources of Bias

Groups similar at baseline were those that were similar in both the RCT and the cohort studies for age, sex, and Cobb angle. No other potential confounders were listed and no adjustment for the most important confounding factors was performed in the observational study.

Information on compliance and cointerventions were not reported in Wan *et al*.³² Compliance was high (95%) and cointerventions were similar across groups in according to the study by Negrini *et al*.²¹ The timing of outcome assessments was similar among groups in studies by both Wan *et al*³² and Negrini *et al*.²¹

In the observational study, the exposed cohort was representative of the population with idiopathic scoliosis.

In the study by Negrini *et al*,²¹ the main outcome of interest (percentages of braced patients) could have been influenced by the lack of blinding of the treating physician, who was responsible for brace prescription.

Effects of Interventions

Exercises Plus Other Treatments Versus Other Treatments Only

Progression of scoliosis³²:

- *Thoracic curve*: Mean difference 9.00, (95% CI, 5.47–12.53). Statistically significant decrease in favor of the exercise group.
- *Lumbar curve*: Mean difference 8.00, (95% CI, 5.08–10.92). Statistically significant decrease in favor of the exercise group.

There was no evidence for patient-related outcomes of cosmetic improvement, general improvement, disability, or back pain.

Different Kind of Exercises Versus Each Other

Progression of scoliosis.²¹ Considering the per protocol analysis, the RR for brace prescription was 0.24, (95% CI, 0.06–1.04). For the intention-to-treat analysis: RR 0.37, (95% CI, 0.13–1.05).

In terms of Cobb angle degree, the RR for patients' improvement was 2.23 (95% CI, 0.73–6.76); the RR for patients getting worse was 0.89 (95% CI, 0.26–3.06). The RR for patient stability was 0.85 (95% CI, 0.64–1.15). The differences were not statically significant.

- With regard to the angle of trunk rotation, the RR for improvement was 3.34 (95% CI, 0.36–30.68), for patients getting worse 0.56 (95% CI, 0.21–1.47), for stability 1.11 (95% CI, 0.85–1.47). The differences were not statically significant.

The quality of evidence concerning the use of SSEs to reduce progression of scoliosis is very low. There are no studies on the efficacy of SSE to improve cosmetic issues, QoL and disability, back pain, and psychological issues.

DISCUSSION

Summary of Main Results

Despite a comprehensive search of published and unpublished literature, we found only 2 studies that met the strict inclusion criteria. There was very low-quality evidence from 2 studies^{21,32} indicating that SSEs added to other treatments are more effective than electrostimulation, traction, and postural training to avoid scoliosis progression, and that SSEs alone has almost similar results to usual physiotherapy. No

TABLE 1. Characteristics of Included Studies*

Methods		Randomized Controlled Trial	
Participants	Eighty patients with double curve (S-shaped) scoliosis. Mean age: 15 ± 4; female: 43. 50 double curves (right thoracic and left lumbar); 30 had left thoracic and right lumbar curves.		
	Exclusion criteria: single curve (C-shaped) scoliosis.		
	Mean Cobb angle at start was: thoracic 25 ± 13°, lumbar 23 ± 11°.		
Interventions	Experimental: N = 40: The same as control plus gymnastic exercise for correction of essential S-shaped scoliosis. Exercises were performed in a lying or creeping position, once a day.		
	Control: N = 40: Electro-stimulation on the lateral body surface by a therapeutic apparatus for correction of lateral curvature. The duration of therapy was increased gradually, beginning with 3 times a day for 30 min each. On the second day, it was twice for 1 hr each. On the third day it was once for 3 hr. Thereafter, treatment was increased by 1 hr every day until it reached 8 hr per day. Subsequently, it progressed to traction therapy. When the curvature is pronounced in the upper body, mandibular traction is done using pelvic traction for obvious lateral curvature twice a day, with each session lasting 30 min. Both groups also underwent postural training during treatment. Patients were advised to maintain a straight, symmetrical posture during normal activities.		
Outcomes	Progression of scoliosis (Cobb angles in degrees assessed by radiographs). Difference between baseline and 6-month follow-up.		
Notes			
Risk of bias		Authors' judgment	Support for judgment.
Random sequence generation (selection bias)		Unclear risk	"Patients were randomly divided into two groups."
Allocation concealment (selection bias)		Unclear risk	"Patients were randomly divided into two groups."
Blinding (performance bias and detection bias)		High risk	Blinding of patients not possible for the kind of intervention.
All outcomes—patients			
Blinding (performance bias and detection bias)		High risk	Blinding of providers not possible for the kind of intervention.
All outcomes—providers			
Blinding (performance bias and detection bias)		High risk	"The planning, execution and evaluation were all carried out by the author; The first author used SPSS version 10.0 statistical software (SPSS Inc., Chicago, IL) to manage data. This was used to compare before and after treatment in association with testing.
All outcomes—outcome assessors			
Incomplete outcome data (attrition bias)		Low risk	No dropouts from the study.
Were drop out reported and equal between groups?			
Incomplete outcome data (attrition bias)		Low risk	
Were all randomized participants analyzed in the group to which they were allocated?			
Selective reporting (reporting bias)		Low risk	
Group similar at baseline	Low risk	Thoracic Cobb angle was 25° ± 13°, and the lumbar one was 23° ± 11° in the control group.	
		Thoracic Cobb angle was 26° ± 12 ° and the lumbar one was 24° ± 10 ° in the experimental group.	
Cointervention	Unclear risk	Information not reported.	
Compliance with interventions	Unclear risk	Information not reported.	
Similar outcome timing	Low risk		
Representativeness of the exposed cohort	High risk	Not assessed for RCT.	
Selection of the non exposed cohort	High risk	Not assessed for randomized controlled trial.	
Ascertainment of exposure	High risk	Not assessed for randomized controlled trial.	
*From Wan et al. ³²			

*From Wan et al.³²

TABLE 2. Characteristics of Included Studies*

Methods		Prospective Controlled Cohort Study
Participants	Seventy-four adolescents with idiopathic scoliosis; mean age: 12.4 yr, females: 52. Mean Cobb angle at the start of treatment was 15° (SD, 6°), while the mean ATR was 7° (SD, 2°).	
	Inclusion criteria were: adolescent idiopathic scoliosis not previously treated, and diagnosed as at risk of bracing according to the Italian Clinical Guidelines and expert medical judgment: (1) proven radiographical progression; (2) Cobb angle exceeding 15° or Bunnell ATR exceeding 7°, first signs of puberty, premenarchal and Risser value 0–1; (3) Cobb angle exceeding 20° and Risser value of 2 or 3.	
	Exclusion criteria: secondary scoliosis and pathologies known as possible causes of scoliosis, neurological deficits, a difference in inferior limb length exceeding 10 mm, previous treatment for scoliosis (brace, exercises or surgery) and Risser value exceeding 3.	
Interventions	Experimental: N = 35: SEAS exercises according to the ISICO approach.	
	The SEAS protocol consists of an individual education session at specialized ISICO Center (1.5-hr session every 2–3 mo) and exercises are then performed by the patient twice a week at home or at a gym. Main elements of SEAS Approach are Active Self-Correction, a complex movement to obtain the best 3-dimensional alignment of scoliotic spine associated with “distracting” elements (imbalance, external weight, coordination task) for improvement of spine stabilization and to obtain the neuromotor rehabilitation.	
	Control: N = 39: Usual physiotherapy group: many different exercise protocols at a local facility according to the preferences of their single therapist. In most cases the exercises were performed in a group context, while in all cases they lasted 45 to 90 min and were performed 2 or 3 times per wk. In some cases, the patients were required to repeat their exercises daily at home.	
Outcomes	Progression of scoliosis as measured by Cobb angle progression and ATR.	
	Progression of scoliosis as measured by number of braces patients within 1 yr follow-up.	
Risk of bias		Authors' judgment
Random sequence generation (selection bias)		Support for judgment.
Allocation concealment (selection bias)		Prospective controlled cohort study.
Blinding (performance bias and detection bias)		Prospective controlled cohort study: “The patients themselves decided whether they preferred to be treated according to our exercise protocol (the SEAS group) or by a rehabilitation center or single physiotherapist of their choice (the UP group). They were thus divided into 2 groups through self-selection.”
All outcomes—patients		Blinding of patients not possible for the kind of intervention.
Blinding (performance bias and detection bias)		Blinding of providers not possible for the kind of intervention.
All outcomes—providers		
Blinding (performance bias and detection bias)		“Physicians were neutral observers because they were not aware of the study being performed and they were focused only on the patients' needs, although they were not blinded to the treatment applied.”
All outcomes—outcome assessors		
Incomplete outcome data (attrition bias)		There were 5 dropouts: 2 in the SEAS group and 3 in the UP group.
Were drop out reported and equal between groups?		
Incomplete outcome data (attrition bias)		The 5 patients who dropped out were included in the worst-case analysis.
Were all randomized participants analyzed in the group to which they were allocated?		

(Continued)

TABLE 2. (Continued)

Methods	Prospective Controlled Cohort Study	
Selective reporting (reporting bias)	Low risk	
Group similar at baseline	Low risk	No difference in mean age. No statistically significant difference was found between the 2 groups at baseline for any of the scoliosis parameters.
Cointervention	Low risk	Patients were required to perform sport activities. No other intervention was provided.
Compliance with interventions	Low risk	"The number of sessions per week was 2.0, min per session were 48, and compliance rate 95%. In addition, no differences were found between the 2 groups with respect to these parameters."
Similar outcome timing	Low risk	
Representativeness of the exposed cohort	Low risk	The sample is truly representative of the average adolescent with scoliosis.
Selection of the non exposed cohort	Low risk	The sample has been drawn from the same community as the exposed cohort.
Ascertainment of exposure	Low risk	Clinical records.
*From Negrini et al. ¹¹		
ATR indicates angle of trunk rotation; ISICO, Italian Scientific Spine Institute; SEAS, Scientific Exercise Approach to Scoliosis; UP, usual physiotherapy.		

data were found regarding the patient-centered outcomes of QoL, back pain, psychological and cosmetic issues.

Overall Completeness and Applicability of Evidence

According to the evidence included in this review, the main finding is that there seems to be no evidence for or against exercises. The article by Wan *et al*³² did not provide enough details to replicate his protocol. Conversely, Negrini *et al*²¹ described the intervention protocol in great detail; however, no details are given regarding usual physiotherapy because even the author was unaware of what was going on in the control group because it was quite heterogeneous and managed by independent therapists.

Out of the outcome measures chosen for this review, only data about radiological findings (Cobb angles) measuring curve magnitude and progression rate were available. This is one of the objectives of exercise, and it is relevant for patients because curve progression can increase the risk of more aggressive treatments like bracing. Usually, progression is measured in terms of Cobb degrees; despite being the most used measure, this is a surrogate endpoint because it is an indirect measure of the risk of future problems such as back pain, trunk decompensation, and future progression during adulthood.⁴ Other possible measures of progression are angle of trunk rotation, and brace prescription rate that were used in the Negrini study.³³ Brace prescription rate is a relevant outcome for patients because it is a more aggressive treatment.¹⁴ The limit of this outcome measure is that it is subjective, and potentially prone to bias. If the physician prescribing the brace is blinded to the

study outcomes, these data are reliable, otherwise it can introduce a bias. This is exactly the same for surgery prescription/performance, which is one of the main outcomes for brace studies according to SRS criteria.

Other outcomes should be considered, mainly QoL, cosmetic and psychological issues because these are more relevant during adolescence than adulthood. Unfortunately, none of the articles meeting the inclusion criteria included these patient-centered outcomes within their studies.

Clinical Relevance

This review suggests that to date because of a lack of high-quality RCTs in this area, there is no evidence for or against exercises, and hardly any clinical recommendations can be given.

As stated in the background to this review, the use of exercise for the treatment of AIS is controversial. Although it is currently routinely used in France, Germany, Italy, and a number of other countries in continental Europe, most centers in the United Kingdom and the United States do not advocate its use. Until a high-quality RCT is conducted, we will not know for certain whether SSEs are effective or not. A National Institute for Health Research Health Technology Assessment feasibility study is currently being conducted in the United Kingdom. If the results of this study are positive, then the first well-conducted RCT can be performed and evidence found.

No statistically significant effects of SSE were found.

No major risks of the intervention have been reported in the literature, and no side effects were cited in the considered studies.

Wan et al ³¹	Negrini et al ¹¹	
?	-	Random sequence generation (selection bias)
?	-	Allocation concealment (selection bias)
-	-	Blinding (performance bias and detection bias): All outcomes—patients
-	-	Blinding (performance bias and detection bias): All outcomes—providers
-	-	Blinding (performance bias and detection bias): All outcomes—outcome assessors
+	+	Incomplete outcome data (attrition bias): Were drop out 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)
+	+	Group similar at baseline
?	+	Cointervention
?	+	Compliance with interventions
+	+	Similar outcome timing
-	+	Representativeness of the exposed cohort
-	+	Selection of the non exposed cohort
-	+	Ascertainment of exposure

Figure 2. “Risk of bias” summary: review authors’ judgments about each risk of bias item for each included study.

Quality of the Evidence

There is no evidence for or against the use of SSE for treating idiopathic scoliosis. Moreover, it must be stressed that the results regarding brace prescription reported in Negrini *et al*²¹ were at high risk of detection bias because the physicians who prescribed the treatments, and who probably believed in their efficacy, were also the physicians who assessed the outcomes and decided whether or not braces should be prescribed or not.

Potential Biases in the Review Process

The strength of the review is the extensive and comprehensive searches conducted, including a large number of different sources in many languages. The main weakness of the review is the absence of high-quality studies in this field that make it impossible to reach any firm conclusions.

Agreements and Disagreements With Other Studies or Reviews

In 2 previous reviews conducted on the effectiveness of SSEs,^{9,20} a greater number of studies of lower methodological quality were included: although the quality of the available studies was low, results were consistent in favor of the efficacy of SSE. In this review because it was necessary to limit

the search to high-quality studies, these results could not be confirmed

CONCLUSION

Implications for Practice

There is lack of high-quality evidence to recommend the use of SSEs for AIS. One very low-quality study³² suggested that these exercises may be more effective than electrostimulation, traction, and postural training to avoid scoliosis progression, but better quality research needs to be conducted before the use of SSEs can be recommended in clinical practice.

Implications for Research

More RCTs are needed to clarify the real role of SSEs as a treatment modality for mild to moderate AIS compared with no treatment. In addition to this overriding goal, further research should also endeavor to clearly define the best types of SSEs for different curve types as well as the most effective methods (frequency and intensity) among those available. To achieve this, multicenter studies carried out by key international research centers on matched groups of scoliosis patients need to be conducted.

➤ Key Points

- ❑ A systematic review assessed the effects of SSEs for AIS
- ❑ Two studies (154 participants) were included: one RCT and one prospective controlled
- ❑ There is low-quality evidence from one randomized controlled study that exercises as an adjunctive to other conservative treatments increase the efficacy of these treatments
- ❑ Better quality research needs to be conducted before the use of SSE can be recommended in clinical practice.

Acknowledgment

The authors thank Rachel Couban, Trials Search Coordinator of the Cochrane Back Review Group, for her help with the search strategies.

References

1. Society. SR. The Scoliosis Research Society Brace Manual. Introduction. 2007. Available at: http://www.srs.org/professionals/bracing_manuals/section1.pdf. Accessed May 11, 2013.
2. Weinstein SL, Ponseti IV. Curve progression in idiopathic scoliosis. *J Bone Joint Surg Am* 1983;65:447–55.
3. Lonstein JE. Scoliosis: surgical versus nonsurgical treatment. *Clin Orthop Relat Res* 2006;443:248–59.
4. Weinstein SL, Dolan LA, Spratt KF, et al. Health and function of patients with untreated idiopathic scoliosis: a 50-year natural history study. *JAMA* 2003;289:559–67.
5. Negrini S, Aulisa AG, Aulisa L, et al. 2011 SOSORT guidelines: orthopaedic and rehabilitation treatment of idiopathic scoliosis during growth. *Scoliosis* 2012;7:3.
6. Omeroglu H, Ozekin O, Bicimoglu A. Measurement of vertebral rotation in idiopathic scoliosis using the Perdriolle torsionmeter: a clinical study on intraobserver and interobserver error. *Eur Spine J* 1996;5:167–71.
7. Weiss HR. Measurement of vertebral rotation: perdriolle versus raimondi. *Eur Spine J* 1995;4:34–8.
8. Reichel D, Schanz J. Developmental psychological aspects of scoliosis treatment. *Pediatr Rehabil* 2003;6:221–5.
9. Lenssinck ML, Frijlink AC, Berger MY, et al. Effect of bracing and other conservative interventions in the treatment of idiopathic scoliosis in adolescents: a systematic review of clinical trials. *Phys Ther* 2005;85:1329–39.
10. Hawes MC. The use of exercises in the treatment of scoliosis: an evidence-based critical review of the literature. *Pediatr Rehabil* 2003;6:171–82.
11. Negrini S, Zaina F, Romano M, et al. Specific exercises reduce brace prescription in adolescent idiopathic scoliosis: a prospective controlled cohort study with worst-case analysis. *J Rehabil Med* 2008;40:451–5.
12. Ducongé P. La rééducation de la scoliose. *Mythe ou réalité? Résonances Européennes du Rachis* 2002;10:1229–36.
13. Weiss HR, Weiss G, Schaar HJ. Incidence of surgery in conservatively treated patients with scoliosis. *Pediatr Rehabil* 2003;6:111–8.
14. Weiss HR, Negrini S, Hawes MC, et al. Physical exercises in the treatment of idiopathic scoliosis at risk of brace treatment – SOSORT consensus paper 2005. *Scoliosis* 2006;1:6.
15. Kotwicki T, Kinel E, Stryla W, et al. Estimation of the stress related to conservative scoliosis therapy: an analysis based on BSSQ questionnaires. *Scoliosis* 2007;2:1.
16. Romano M, Carabalona R, Petrilli S, et al. Forces exerted during exercises by patients with adolescent idiopathic scoliosis wearing fiberglass braces. *Scoliosis* 2006;1:12.
17. Negrini S, Negrini A, Romano M, et al. A controlled prospective study on the efficacy of SEAS.02 exercises in preparation to bracing for idiopathic scoliosis. *Stud Health Technol Inform* 2006;123: 519–22.
18. Zaina F, Negrini S, Atanasio S, et al. Specific exercises performed in the period of brace weaning can avoid loss of correction in Adolescent Idiopathic Scoliosis (AIS) patients: Winner of SOSORT's 2008 Award for Best Clinical Paper. *Scoliosis* 2009;4:8.
19. Mamyama T, Kitagawa T, Takeshita K, et al. Side shift exercise for idiopathic scoliosis after skeletal maturity. *Stud Health Technol Inform* 2002;91:361–4.
20. Negrini S, Antonini G, Carabalona R, et al. Physical exercises as a treatment for adolescent idiopathic scoliosis. A systematic review. *Pediatr Rehabil* 2003;6:227–35.
21. Negrini S, Fusco C, Minozzi S, et al. Exercises reduce the progression rate of adolescent idiopathic scoliosis: results of a comprehensive systematic review of the literature. *Disabil Rehabil* 2008;30:772–85.
22. Negrini S, Minozzi S, Bettany-Saltikov J, et al. Braces for idiopathic scoliosis in adolescents. *Cochrane Database Syst Rev* 2010;CD006850. doi: 10.1002/14651858.CD006850.pub2.
23. Society S-SR. Brace Wear Compliance; 2006. Available at: http://www.srs.org/professionals/bracing_manuals/section3.pdf. Accessed May 11, 2013.
24. Rigo M, Quera-Salva G, Villagrasa M. Sagittal configuration of the spine in girls with idiopathic scoliosis: progressing rather than initiating factor. *Stud Health Technol Inform* 2006;123: 90–4.
25. Asher M, Min Lai S, Burton D, et al. The reliability and concurrent validity of the Scoliosis Research Society-22 patient questionnaire for idiopathic scoliosis. *Spine (Phila Pa 1976)* 2003;28: 63–9.
26. Vasiladias E, Grivas TB, Savvidou O, et al. The influence of brace on quality of life of adolescents with idiopathic scoliosis. *Stud Health Technol Inform* 2006;123:352–6.
27. Furlan AD, Pennick V, Bombardier C, et al. 2009 Updated method guidelines for systematic reviews in the Cochrane Back Review Group. *Spine (Phila Pa 1976)* 2009;34:1929–41.
28. Higgins JPT, Green S (Eds). *Cochrane Handbook for Systematic Reviews of Interventions Version 5.0.2* [Updated September 2009]; The Cochrane Collaboration. Available at: www.cochrane-handbook.org. Accessed May 11, 2013.
29. Wells G, Shea B, O'Connell D, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses; 2008. Available at: www.ohri.ca/programs/clinical_epidemiology/oxford.htm. Accessed May 11, 2013.
30. Shekelle PG, Andersson G, Bombardier C, et al. A brief introduction to the critical reading of the clinical literature. *Spine* 1994;19: 2028S–31S.
31. Atkins D, Best D, Briss PA, et al. Grading quality of evidence and strength of recommendations. *BMJ* 2004;328:1490.
32. Wan L, Wang G-X, Rong B. Results of exercise therapy in treatment of essentially S-shaped scoliosis patients: evaluations of Cobbs angle in the breast and lumbar segment. *Chin J Clin Rehabil* 2005;9:82–4.
33. Negrini S, Zaina F, Romano M, et al. Specific exercises reduce brace prescription in adolescent idiopathic scoliosis: a prospective controlled cohort study with worst-case analysis. *J Rehabil Med* 2008;40:451–5.