Effects of corrective, therapeutic exercise techniques on adolescent idiopathic scoliosis. A systematic review

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ABSTRACT

The objective of this study was to determine the effects of corrective, therapeutic exercise techniques on subjects with adolescent idiopathic scoliosis. A systematic review was conducted by searching the Cochrane Library Plus, Pubmed, PEDro, and SCOPUS databases. Studies in patients diagnosed with adolescent idiopathic scoliosis that considered corrective, therapeutic exercise as an independent outcome measure and symptoms, functional capacity, Cobb's angle and/or other angles or body asymmetries as dependent outcome measures were included. A total of 9 controlled clinical trials that carried out corrective, therapeutic exercise were included. Corrective, therapeutic exercise appears to have positive effects by reducing symptoms and improving function, as well as various angles and body asymmetries. However, further studies with better methodological quality are required to confirm these outcomes and determine the best therapeutic exercise intervention.

Key words: *scoliosis, adolescent, applied kinesiology.*

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INTRODUCTION

A spinal deformity is called "scoliosis" when the spine shows a frontal deviation with a spinal curvature (Cobb's angle) of 10° or more, and it is associated with rotation of the vertebral bodies.[1] Specifically, adolescent idiopathic scoliosis (AIS) is the most common spinal deformity and has a high diagnostic relevance in the pediatric population, mostly during adolescence.[2]

In general, between 2% and 4% of youth aged 10-16 years have AIS, which accounts for 84-89% of all subjects with scoliosis.[3] Approximately 10% of these AIS cases progress and may be associated with other anomalies, especially neurological disorders.[4] Given all these manifestations, the early diagnosis and management are critical for a better quality of life.

The characteristic signs of AIS are chest deformities, protuberances, and asymmetries.[5] Although it is not the main clinical factor, patients with AIS may have pain; they are more prone to pain when the degree of Cobb's angle is higher.[6] Studies on AIS prevalence have demonstrated that between 27% and 59% of patients suffer pain.[5,7] In addition, it may be associated with other conditions, such as restricted ventilation, respiratory muscle weakness, reduced quality of life,[8] and even psychological problems.[9]

At present, according to the 2016 AIS consensus,[1] follow-up and management include observation, bracing or surgery. The Scoliosis Research Society (SRS) suggests bracing for patients with a Cobb's angle greater than 25°. Surgery is indicated for subjects with a Cobb's angle greater than 45°-50°. In relation to conservative management, several therapeutic exercise interventions have been proposed for this population; their implementation has been recommended not only for those for whom surgery is not indicated but also in combination with other measures, such as braces. The objective of exercise is to reduce symptoms and improve functional capacity and quality of life.[10-15] Although braces are mainly used in these patients, the isolated effects of corrective, therapeutic exercise on AIS patients are not clear;[1] actually, the Scientific Society on Scoliosis

Orthopaedic Rehabilitation and Treatment (SOSORT)[16] has shown that the evidence of conservative management in these patients is scarce.

The objective of this study was to determine, through a systematic review, the effects of corrective, therapeutic exercise on patients diagnosed with AIS.

METHODS

A systematic review was conducted in accordance to the Preferred Reporting Items in Systematic Reviews and Meta-Analyses (PRISMA) Statement.[17]

Eligibility criteria

The eligibility criteria to select articles were established based on the SOSORT's recommendations:[18]

- Controlled clinical trials (CCTs).
- Specification that sample subjects had been diagnosed with AIS and had a Cobb's angle of 10º-45º.
- A sample of pediatric patients according to the regulations of the country where the study is conducted. According to the Spanish Society of Pediatrics, 51.7% of countries considered that pediatric age covered patients from 0 to 18 years old.[19]
- An intervention based on corrective, therapeutic exercise as an independent outcome measure and a comparison with a placebo or control group or with other non-surgical techniques.
- At least one of the following dependent outcome measures: symptoms, functional capacity, Cobb's angle and/or other angles or body asymmetries.

Exclusion criteria:

- Any other surgical or brace intervention.

Article search

CCTs were searched in the following databases recognized by the scientific community: The Cochrane Library Plus, Pubmed (MEDLINE), Physiotherapy Evidence Database (PEDro), and SCOPUS between February and October 2017. Articles in English, French or Spanish were considered for inclusion, and no limits were set on publication dates.

The following Medical Subject Headings (MeSH) were used: scoliosis, physical therapy modalities, exercise, and conservative treatment, and their combination, depending on the search engine, together with the Boolean operators AND and OR. Articles mentioned in the bibliography of main articles were also reviewed so as not to overlook potentially relevant studies.

Article identification

Two independent reviewers applied the eligibility criteria to select potentially relevant studies based on the titles and abstracts of articles found after searching the different databases mentioned above. A consensus was established for article inclusion. Then, the full texts of studies that met the eligibility criteria were retrieved. Data were collected in the same manner by two independent reviewers. The author and year of publication, sample size, participants' age, intervention, symptoms, Cobb's angle, neck slope angle, trunk rotation, body asymmetries, functional capacity, muscle endurance, pulmonary function, and outcomes of each study were recorded. A third reviewer cleared up any doubts or disagreement that may have arisen while selecting studies.

Assessment of methodological quality

Likewise, two independent persons assessed the methodological quality of the CCTs included using the PEDro scale (*Table 1*), which assessed the methodological quality of studies, considering that studies were of high quality if they scored 6-10, of moderate quality if they scored 4-5, and of low quality if they scored 0-3,[20] and the levels of evidence of the Oxford Centre of Evidence-Based Medicine (OCEBM) (*Table 2*), a criterion for harmonization recommended by the SOSORT.[18]

RESULTS

Study selection

A total of 1206 articles were retrieved from the different analyzed databases; finally, 15 were considered for a detailed review. Among these, 1[21] was excluded because the sample was not diagnosed with AIS; 2,[22,23] because bracing was used in the intervention group; 2,[24,25] because they were not based on therapeutic exercise; and 1,[26] because it was not a CCT. Finally, a total of 9 clinical trials were included for analysis. The article selection process is shown in a flow chart (*Figure 1*).

Study characteristics

All articles corresponded to CCTs written in English. In relation to the range of years of publication, the oldest article was from 2012 and

the latest, from 2017. The sample size ranged from 24 to 110 participants. All samples from included CCTs totaled 459 patients, divided into 2 groups, except for a study that had 3 groups.[27] All subjects included in the groups were diagnosed with AIS and were in the pediatric age range.

All included studies had corrective, therapeutic exercise as the independent outcome measure; 4 referred to it as Schroth exercises,[27-30] and the other 5 used different terms that covered therapeutic exercise based on self-correction and spinal stabilization.[31-35] The intervention period varied greatly: 3 studies included an intervention that lasted 8-12 weeks,[30,32,35] while 4 conducted interventions for 6 months,[27-29-33] and 2, for 1 year.[31,34]

In relation to dependent outcome measures, 6 studies assessed symptoms using the following questionnaires: Scoliosis Research Society 22 (SRS-22),[28,34] Scoliosis Research Society 23 (SRS-23),[27] Numeric Pain Rating Scale (NPRS),[32,33] and Functional Rating Index (FRI).[35]

Six studies assessed postural parameters, such as Cobb's angle, measured using anterior-posterior X-rays of the trunk with the patient standing,[27,29-31,34] neck slope angle, measured using a sagittal photogrammetry with the patient sitting down,[35] angle of trunk rotation, measured using an inclinometry[27,34] and/or body asymmetries, measured using stereographic projections[35] or a rigid ruler.[27]

TABLE 1. *Physiotherapy Evidence Database (PEDro scale)*

1. Eligibility criteria were specified.	No ☐	Yes ☐	Where:
2. Subjects were randomly allocated to groups (in a crossover study, subjects were andomly allocated as treatments were administered).	No ☐	Yes ☐	Where:
3. Allocation was concealed.	No ☐	Yes ☐	Where:
4. The groups were similar at baseline regarding the most important prognostic indicators.	No ☐	Yes ☐	Where:
5. There was blinding of all subjects.	No ☐	Yes ☐	Where:
6. There was blinding of all therapists who administered the therapy.	No ☐	Yes ☐	Where:
7. There was blinding of all assessors who measured at least one key outcome.	No ☐	Yes ☐	Where:
8. Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups.	No ☐	Yes ☐	Where:
9. All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat".	No ☐	Yes ☐	Where:
10. The results of between-group statistical comparisons are reported for at least one key outcome.	No ☐	Yes ☐	Where:
11. The study provides both point measures and measures of variability for at least one key outcome.	No ☐	Yes ☐	Where:

TABLE 2. *Oxford Centre for Evidence-based Medicine – levels of evidence*

Level of recommendation	Level of evidence	Treatment studies
A	1.a	SR with homogeneity of randomized controlled clinical trials.
	1.b	Individual CT with narrow confidence interval.
	1.c	Efficiency demonstrated by clinical practice. Considered when some patients die before the assessment.
B	2.a	SR with homogeneity of cohort studies.
	2.b	Individual cohort study with < 80% of follow-up (including low-quality CTs).
	2.c	Ecological studies or health outcomes research.
	3.a	SR with homogeneity of case-control studies.
	3.b	Individual case-control studies.
C	4	Case-series and poor quality cohort and case-control studies.
D	5	Expert opinion without explicit critical appraisal, or based on physiology or research work.

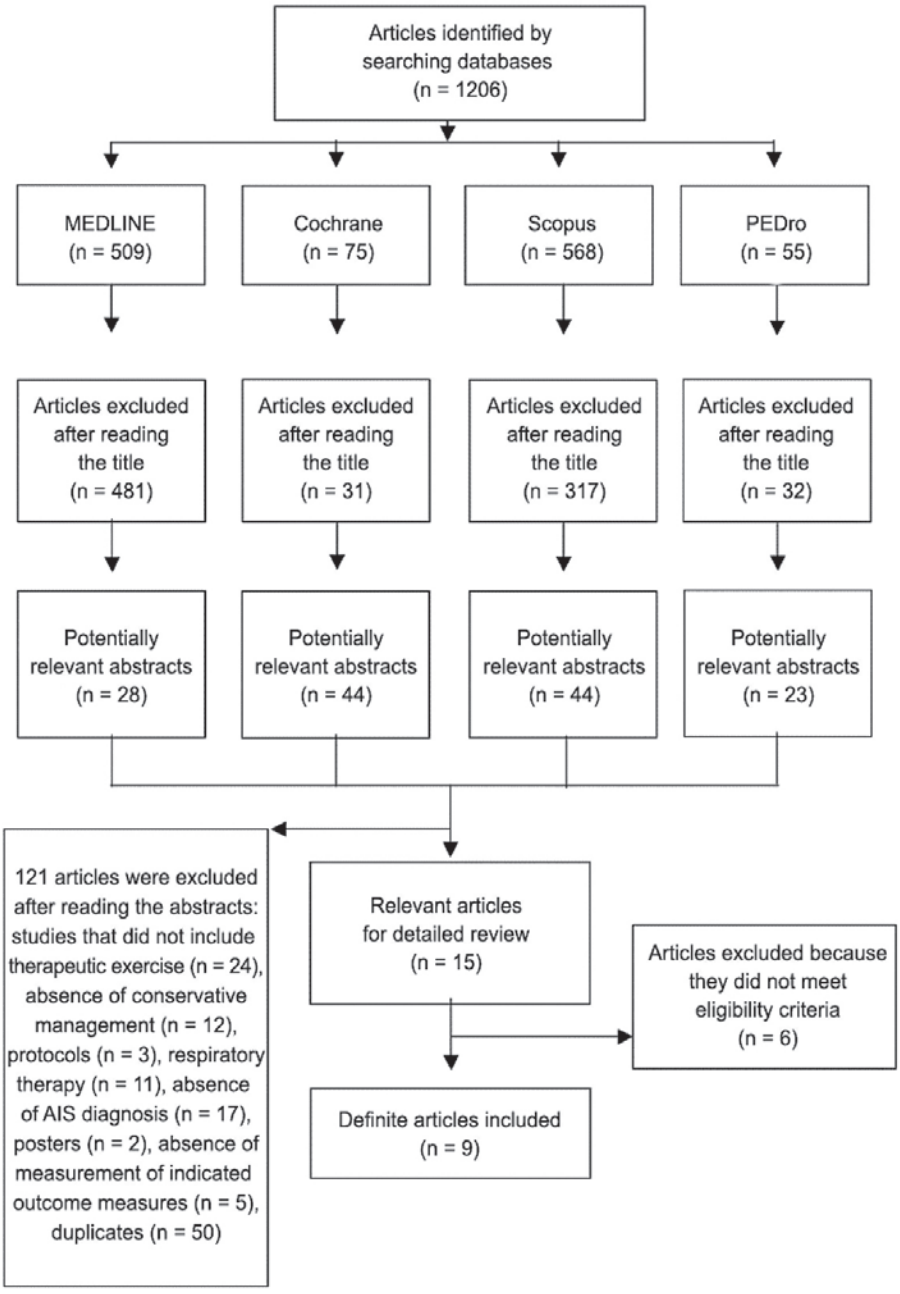
SR: systematic review. CT: clinical trial.

Six studies assessed the functional capacity of included subjects using the following questionnaires: SRS-22,[28,34] SRS-23,[27] Oswestry Low Back Pain Disability Questionnaire (OSW), Patient-Specific Functional Scale (PSFS),[32,33] and FRI.[35]

In relation to muscle endurance, 2 studies assessed back extensor muscle endurance using the Prone-Double-Leg-Raise Test (PDLRT)[32] and the Biering-Sorensen test (BME, back muscle endurance).[28]

Two studies assessed the overall perception following the intervention using the Global Rating of Change (GROC).[32,33]

FIGURE 1. *Flow chart: Article selection process*



AIS: adolescent idiopathic scoliosis.

Only 1 study assessed pulmonary function using pulmonary function tests that measured vital capacity (VC), peak expiratory flow (PEF), forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), and the FEV_1/FVC ratio.[31]

Methodological quality of included studies

Eight of the studies scored 6 or more in the PEDro scale, i.e., had a high quality. Two studies scored 5, which means a moderate quality. Some aspects left room for improvement, such as the lack of patient and observer blinding or the failure to submit results for all study subjects. The detailed PEDro scale scoring is shown in *Table 3*.

All studies showed a level of evidence 1b,[36] which corresponded to an advisable level of recommendation, moderate evidence that the measure was effective and that the benefits were higher than the detriments, as established by randomized clinical trials with a very low risk for bias.

Therapeutic effectiveness

The results for each dependent outcome measure obtained after each treatment implemented in the clinical trials included in this review are shown in detail in *Table 4*.

DISCUSSION

The objective of this review was to determine the effects of corrective, therapeutic exercise on patients diagnosed with AIS.

The outcomes described in included articles showed that therapeutic exercise had been effective to reduce symptoms, Cobb's angle, craniovertebral angle, trunk rotation, and body asymmetries, and to improve muscular endurance, pulmonary function, and functional capacity of patients with AIS.[27-35]

AIS symptoms are frequently associated with tumors, inflammation or visceral dysfunction; this would exclude solely conservative management. The studies encompassed by this review did not include that type of patients and, after the intervention, they showed a reduction in symptoms. The bibliography is not unanimous about how AIS symptoms start.[6] Some authors have attributed them to the asymmetric burden that causes early intervertebral disc and facet degeneration and shortening of the muscles.[6,37,38] However, the mechanism that leads to the improvement in such outcome measure is not known accurately, given that it may be the result of an improved flexibility in the spine and adjacent tissues[39] or the release of pain modulatory substances resulting from exercise itself.[40]

An article described improvements in pulmonary capacity.[31] Respiratory alterations are more frequent as the Cobb's angle increases;[41] therefore, bracing –or even surgery– would be recommended for these patients.[1] However, this information should be taken with caution because it has only been observed in 1 study.

Another finding observed in included articles is the improvement in postural outcome measures. The fact that an effect occurred on self-correction and postural control may have helped to stretch tissues on the concave side and modify tissue tension on the convex side of scoliosis. In addition, a key aspect of understanding the biomechanics of these exercises is the activation of the muscles involved in spinal stabilization, such as the multifidus muscle, the rotator group, and the transverse abdominal muscle, etc., which would help to improve postural balance and muscle function; improvements in muscular endurance tests may also be related to this.[42,43]

Findings, collectively, show an improved posture that lies in the ability to maintain self-

TABLE 3. *Methodological quality. PEDro scale score*

Article	1	2	3	4	5	6	7	8	9	10	TOTAL
Diab et al., 2012	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	7/10
Monticone et al., 2014	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	8/10
Zapata et al., 2015	Yes	No	Yes	No	No	Yes	No	No	Yes	Yes	5/10
Schreiber et al., 2015	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	8/10
Kuru et al., 2016	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	6/10
Schreiber et al., 2016	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	8/10
Kim et al., 2016	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6/10
Zapata et al., 2017	Yes	No	Yes	No	No	Yes	No	No	Yes	Yes	5/10
Kumar et al., 2017	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	8/10

correction and postural control over time. Previous studies have supported the benefits of therapeutic exercise by demonstrating that corrective exercises may prevent progression of the curvature[14] and may even avoid bracing[11] and surgery.[44]

The improvements in functional capacity and quality of life observed after therapeutic exercise in patients with AIS may be attributed to a reduction in symptoms which, together with better postural parameters, may have influenced patients' self-image and personal satisfaction.

In relation to the number of weekly sessions, a controversial aspect in other research studies,[45] there is no uniform criterion regarding the number or duration of sessions; in addition, some studies considered both in-person and remote sessions. It is worth noting that the learning and control abilities vary from one subject to another; therefore, it is difficult to estimate the intensity and duration of interventions.

This study does not assess the combined

TABLE 4. *Summary of results*

Author	N	Age (years) Mean ± SD	Intervention	Outcome measures	Results
Diab et al., 2012	G1: 38	13.2 ± 1.2	G1: control group	Craniovertebral angle, trunk inclination, lordosis, kyphosis, imbalance, lateral deviation, pelvic torsion and rotation FRI	G1-G2: $p < 0.05$; improvement in G2 after 10 weeks and 3 months
	G2: 38	14.5 ± 1.3	G2: postural self-correction group		G1-G2: $p < 0.05$; improvement in G2 after 3 months
Monticone et al., 2014	G1: 55	12.5 ± 1.1	G1: control group	Cobb's angle, TRA, SRS-22	G1-G2: $p < 0.001$; improvement in G2 after treatment and after 12 months
	G2: 55	12.4 ± 1.1	G2: stabilization group		
Zapata et al., 2015	G1: 17	15.7 ± 2.0	G1: stabilization group	NPRS, PSFS	G1-G2: $p < 0.05$; improvement in G1 after 8 weeks
	G2: 17	14.1 ± 2.0	G2: uncontrolled stabilization group		G1: $p = 0.001$ / G2: $p = 0.001$
				OSW, PDLRT	G1: $p = 0.001$ / G2: $p = 0.001$
Schreiber et al.,2015	G1: 25	12.7 ± 1.5	G1: control group	BME test	G1-G2: $p = 0.04$; improvement in G2 after 3 months
	G2: 25	12.7 ± 1.2	G2: Schroth exercise group	SRS-22	G1-G2: $p < 0.05$; improvement in symptoms and function of G2 after 3 months
Kuru et al., 2016	G1: 15	12.9 ± 1.4	G1: Schroth exercise group	Cobb's angle	G1-G2-G3: $p = 0.003$; improvement in G1 after 24 weeks
	G2: 15	13.1 ± 1.7	G2: uncontrolled Schroth exercise group	Rotation angle, hump height, waist asymmetry	G1-G2-G3: $p < 0.01$; improvement in G1 after 6 and 24 weeks
	G3: 15	12.8 ± 1.2	G3: control		
Schreiber et al., 2016	G1: 25	13.5 (12.7-14.2)	G1: Schroth exercise group	Major curve	G1-G2: $p = 0.006$; improvement in G1 after 6 months
	G2: 25	13.3 (12.7-13.9)	G2: control group	Sum of curves	G1-G2: $p = 0.048$; improvement in G1 after 6 months
Kim et al., 2016	G1: 12	15.3 ± 0.8	G1: Schroth exercise group	Cobb's angle, weight distribution between the concave and convex sides	G1-G2: $p < 0.05$; improvement in G1 after 12 weeks
	G2: 12	15.6 ± 1.1	G2: Pilates group		
Zapata et al., 2017	G1: 17	15.5 ± 2.2	G1: stabilization group	NPRS and GROC	G1-G2: $p < 0.05$; improvement in G1 after 6 months
	G2: 17	14.0 ± 2.0	G2: uncontrolled stabilization group	OSW and PSFS	G1: $p < 0.001$ / G2: $p < 0.001$
Kumar et al., 2017	G1: 18	12.1 ± 1.7	G1: control group	Cobb's angle, FVC, FEV1, VC	G1-G2: $p < 0.001$; improvement in G2 after 1 year
	G2: 18	11.5 ± 1.4	G2: postural self-correction group	PEF	G1: $p < 0.05$ / G2: $p < 0.05$

G: group; p: statistical value; TRA: trunk rotation angle; BME: back muscle endurance; FEV1: forced expiratory volume in 1 second; FRI: Functional Rating Index; FVC: forced vital capacity; GROC: Global Rating of Change; NPRS: Numeric Pain Rating Scale; OSW: Oswestry Low Back Pain Disability Questionnaire (revised); PDLRT: Prone-Double-Leg-Raise Test; PEF: peak expiratory flow; PSFS: Patient-Specific Functional Scale; SRS-22r: Scoliosis Research Society Patient Outcomes questionnaire 22r; SRS-23: Scoliosis Research Society Patient Outcomes questionnaire 23; VC: vital capacity.

effects of bracing and therapeutic exercise; it is considered that, in clinical practice, not only one isolated technique is used, and the latter works as an adjuvant measure for the management of AIS.

LIMITATIONS

One of the main limitations was the small number of articles included, which indicates that there is little evidence on the use of therapeutic exercise for the management of this disease.

In addition, some articles failed to describe the methodology appropriately, thus hindering the assessment of methodological quality. All articles left room for improvement in terms of methodological aspects, and it is worth noting the lack of patient and observer blinding and the failure to submit results for all study subjects.

As recommended in the 2014 consensus between the SOSORT and the SRS,[18] the different tools used to measure dependent outcome measures hamper study comparison.

In addition, the low methodological quality of some studies prevented us from including certain exercise techniques, such as global postural reeducation and the Klapp method, which, in clinical practice, are used in these patients.

CONCLUSION

The results of this review appear to point out the positive effects of AIS management with therapeutic exercise based on the Schroth method or stabilization exercises. Therapeutic exercise reduces symptoms and improves function, vertebral angles, and trunk asymmetries. It is not possible to describe the ideal moment for the intervention or the number of weekly sessions and the duration of each session. Therefore, further studies are necessary with a better methodological quality on therapeutic exercise that measure clinical and imaging outcome measures to obtain conclusive results. ■

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