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SYSTEMATIC REVIEW

The effectiveness of Schroth method in Cobb angle, quality of life and trunk rotation angle in adolescent idiopathic scoliosis: a systematic review and meta-analysis

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ABSTRACT

INTRODUCTION: The Schroth method is one of the most common physiotherapeutic scoliosis-specific exercises intervention applied in adolescent idiopathic scoliosis (AIS). This method consists of three-dimensional correction of the specific curve pattern of the patient using a combination of sensorimotor, postural, and corrective breathing exercises. The aim of this systematic review and meta-analysis was to analyse the effects of the Schroth method in isolation on Cobb angle, quality of life, and trunk rotation angle compared to no intervention or other conservative treatments in patients with AIS.

EVIDENCE ACQUISITION: PubMed, Physiotherapy Evidence Database, Scopus, Cochrane Library, and Web of Science databases were searched. Studies were included if they were randomized controlled trials that compared the effects of the Schroth method in isolation to conservative interventions or no intervention. The quality of the studies was assessed with the PEDro Scale, and the risk of bias with the Cochrane Collaboration tool. Two independent assessors extracted data through a standardized form. Meta-analyses were conducted using fixed or random effects models according to the heterogeneity assessed with I^2 coefficient. Data on outcomes of interest were extracted by a researcher using RevMan 5.4 software.

EVIDENCE SYNTHESIS: A total of 317 studies were screened. Six were included in the meta-analysis involving 144 patients with AIS. The methodological quality of the included studies ranged from high to low. Schroth method in isolation showed significant improvements in Cobb angle (mean difference [MD] =-3.18º; 95% CI: -4.30, -2.07; I^2: 0%), quality of life (MD=0.28; 95% CI: 0.18, 0.38; I^2: 0%) and trunk rotation angle (MD=-2.12º; 95% CI: -3.44, -0.80; I^2: 71%) in the short-term.

CONCLUSIONS: The Schroth method in isolation is effective for reducing the Cobb angle and the trunk rotation angle and for improving the QoL in the short-term compared to no intervention or other conservative therapies in AIS, but the improvement in Cobb angle did not exceed the minimum clinically important difference.

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KEY WORDS: Scoliosis; Exercise; Systematic review; Meta-analysis.

Introduction

Adolescent idiopathic scoliosis (AIS) is a three-dimensional spinal deformity that affects the pediatric population.[1] It represents between 84% and 89% of all types of scoliosis.[2]

AIS is diagnosed when the curvature of the spine in the coronal plane, measuring the angle between the upper and the lower limits of the deformity (Cobb angle), is greater than 10º.[1] A curve between 10º to 25º is considered mild, a curve between 25º to 45º is classified as moderate, and a curve > 45º is classified as a severe form of scoliosis.[3]

The Scoliosis Research Society (SRS) developed a standard care guideline using the Cobb angle as the primary outcome. They recommended that treatment should include observation and a brace for mild to moderate curves, and surgery should be used for severe curves. Both techniques have shown to be effective for controlling or reducing the Cobb angle; nevertheless, the Cobb angle is poorly correlated to the overall quality of life (QoL).[4] For this reason, in addition to Cobb angle, it is important to assess patient-related outcomes, such as QoL. According to this, bracing has been related to discomfort, stressful experiences, and negative self-esteem, causing decreased QoL.[5] Moreover, surgery can cause complications, pain, and long recovery periods.[6]

On the other hand, the Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT) recommends scoliosis-specific exercises as an important option to stop or slow the curve progression.[7] SOSORT defines Physiotherapeutic scoliosis-specific exercises (PSSE) as exercises that are individualized and consist of patient education, autocorrection in three dimensions, training in adjusted activities of daily living and stabilization of the correct posture.[3, 8-11]

The Schroth method is one of the most common PSSE interventions.[12] This method consists of three-dimensional correction of the specific curve pattern of the patient in daily activities using a combination of sensorimotor, postural, and corrective breathing exercises.[13] The correction of the scoliotic posture is carried out with exteroceptive and proprioceptive stimulations and mirrors, isometrics, and other exercises to lengthen or strengthen asymmetrical muscles while maintaining a specific breathing pattern.[14] The most important aspect of this method is auto-correction, defined as the patient's ability to reduce spinal deformity through active postural realignment of the spine in three planes.[14] In addition, physiotherapists encourage patients to consciously maintain the proper posture learned during exercise periods in daily living.

Two recent systematic reviews and meta-analyses found positive effects of applying the Schroth method in AIS.[15, 16] However, both included studies that combined the Schroth method with other therapies, such as bracing. To our knowledge, no systematic review with meta-analysis has investigated the effects of the Schroth method in isolation in Cobb angle, QoL, and trunk rotation angle in patients with AIS.

Thus, the aim of this systematic review and meta-analysis was to analyse the effects of the Schroth method in isolation in Cobb angle, QoL, and trunk rotation angle compared to no intervention or other conservative treatments in patients with AIS.

Evidence acquisition

Study design

The protocol of this systematic review was registered in the International Prospective Register of Systematic Reviews (PROSPERO) with registration number CRD42022326940. This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement and the Cochrane recommendation.[17]

Search strategy

The bibliographical search was conducted in PubMed (MEDLINE), Physiotherapy Evidence Database (PEDro), Scopus, Cochrane Library, and Web of Science (WOS) from inception to 18 May 2022. The Population, Intervention, Comparison, Outcome, and studies (PICOs) framework was used to define the search strategy. The keywords used for the search strategy were: "Schroth exercises," "adolescent idiopathic scoliosis," "juvenile idiopathic scoliosis." The strategies used for each database are shown in Supplementary Digital Material 1 (Supplementary Text File 1). The Scopus database was included as a tool for searching grey literature, and a hand search of the reference list of the included studies was performed. Searches were limited to studies in English, French, and Spanish.

Eligibility criteria and study selection

The included studies met the PICOs criteria: 1) males and females aged between 10 and 18 years old diagnosed with AIS; 2) Schroth exercises intervention in isolation; 3) comparison may include conservative interventions defined as a brace and/or exercise regime (such as stretching,

strengthening, yoga, pilates, or taichi); 4) outcomes consisted of Cobb angle, angle of trunk rotation, and quality of life; 5) RCTs.

Studies were excluded if they: 1) included participants with a scoliotic curvature <10º; 2) included participants with scoliosis caused by other pathologies not defined as idiopathic scoliosis; 3) included braces or previous surgery in the intervention group; 4) the outcome variables reported were not the outcomes of interest or were not measured using a valid and reliable instrument.

After the searches were retrieved, references were exported to the Mendeley desktop, and duplicates were removed. Two reviewers independently (LC and AC) assessed the title and abstract of each reference to determine potential eligibility. The same independent reviewers assessed potential full texts. The discrepancies between the two reviewers were resolved by a third author (SJ). Two authors were contacted by e-mail to clarify the eligibility criteria.

Data extraction

The two authors independently extracted the data from the identified studies using a standardized process adapted from the Cochrane Collaboration. Extracted information

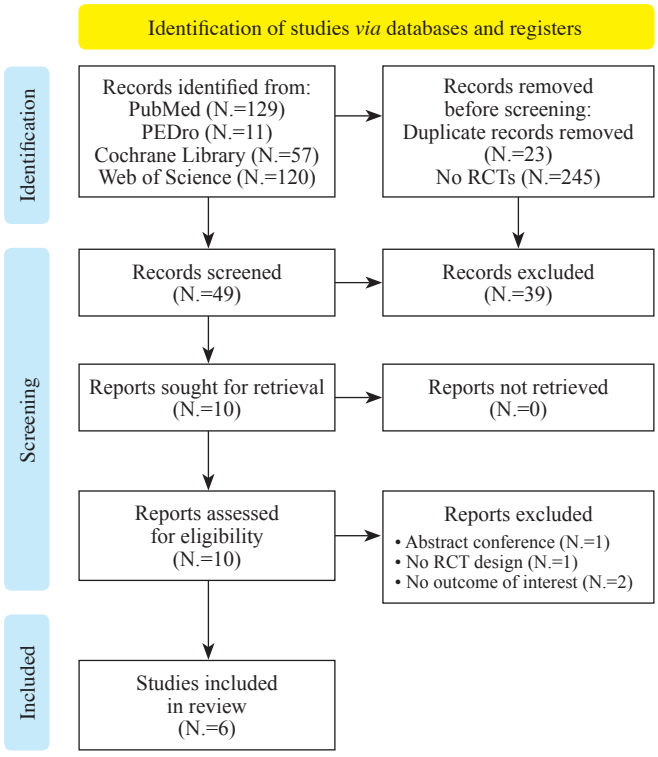

Figure 1.—Flowchart diagram of the study.

TABLE I.—*Sociodemographic and clinical characteristics of the participants.*

Author (year)	N (sex ratio)	Mean Age (SD)	Risser sign considered	Mean Risser sign	Interventions
Schreiber *et al.*[29] 2015	14 (1M/13F)	CG: 14.62 (1.18) EG: 13.83 (1.32)	0-5	CG: 1.44 (0.77 to 2.11) EG: 1.76 (1.10 to 2.45)	Schroth exercises (N.=6) *vs*. standard care (observation or bracing) (N.=8)
Schreiber *et al.*[14] 2016	14 (1M/13F)	CG: 14.57 (1.27) EG: 124.0 (1.29)	0-5	CG: 1.44 (0.77 to 2.11) EG: 1.76 (1.10 to 2.45)	Schroth exercises (N.=7) *vs*. standard care (observation or bracing) (N.=7)
Kim *et al.*,[28] 2016	24 (24F)	CG: 15.3 (0.8) EG: 15.60 (1.1)	NR	NR	Schroth exercises (N.=12) *vs*. Pilates exercises (N.=12)
Kuru *et al.*,[26] 2016	30 (3M/27F)	CG: 12.8 (1.2) EG: 12.9 (1.4)	0-3	CG: 1.0 (1.2) EG: 1.5 (1.3)	Schroth exercises (N.=15) *vs*. no intervention (N.=15)
Kocaman *et al.*,[30] 2021	28 (7M/21F)	CG: 14.21 (2.19) EG: 14.07 (2.37)	0-3	CG: 1.78 (1.19) EG:1.64 (1.34)	Schroth exercises (N.=14) *vs*. core stabilization exercises (N.=14)
Mohamed *et al.*,[27] 2021	34	CG: 14.9 (1.4) EG: 14.5 (1.2)	0-4 CG: II (N.=5) III (N.=5) IV (N.=7) EG: II (N.=6) III (N.=5) IV (N.=6)	CG:3.1 (0.85) EG: 3.0 (0.86)	Schroth exercises (N.=17) *vs*. PNF exercises (N.=17)

SD: standard deviation; CG: control group; EG: experimental group; M: male; F: female; NR: no reported.
↑ statistically significant improvement.

included: 1) characteristics of the study population; 2) a description of the intervention performed; 3) outcome measures; and 4) results. The third assessor resolved any disagreements. Data were analyzed using a qualitative synthesis and, whenever possible, a quantitative synthesis (meta-analysis).

Risk of bias and quality of evidence

The quality of the studies was assessed by two assessors using the PEDro Scale and the Cochrane Risk of Bias tool. The PEDro Scale is an 11-item scale based on the Delphi list developed by Verhagen *et al*.[18] One item of the PEDro Scale (eligibility criteria) was related to external validity and was not used to calculate the total score. A score of seven or above was considered 'high' quality, five and six were considered "fair" quality, and four or below was considered 'poor quality'.[18, 19] The Cochrane Risk of Bias tool determines the potential bias and the internal validity of the studies and classifies them as 'low', 'unclear', or 'high' risk based on seven criteria.[20] Both tools have shown to be reliable for evaluating the quality of the studies and assessing the risk of bias. The funnel plots are presented with a description of the risk of bias in each study assessed in the supplementary material (Supplementary Digital Material 2: Supplementary Figure 1, Supplementary Figure 2, Supplementary Figure 3).

The quality of the evidence was assessed using GRADE Evidence Profiles. This classification categorizes the evidence as 'high', 'moderate', 'low', or 'very low' and allows to discern the importance of the results. The quality of evidence for the meta-analysis was downgraded according to the presence of the following: risk of bias (downgraded by one level or two levels if more than 25% or 50% of the participants came from studies with poor or fair methodological quality: lack of randomization or allocation concealment, no sample size estimation, or no participants or assessors blinding), inconsistency of results (downgraded by one level if there was significant heterogeneity regarding outcome measurement or intervention or if the I^2 value was ≥50%. It was reduced two levels when I^2 was ≥75%), indirectness of evidence (downgraded by one level if different populations, interventions, or comparators were included), and imprecision (downgraded by one level if a 95% confidence interval [95% CI] of a standardized mean difference [SMD] was >0.2 points, two levels if it was >0.5 points in either direction. One level was also downgraded if the 95% CI of the

Outcome (tool)	Main Results	Exercise time per day	Frequency	Duration	PEDro
QoL (SRS-22)	↑ QoL in EG *vs*. CG	30-45 min	5 days/week	24 weeks	8
Cobb angle	No between groups differences	30-45 min	5 days/week	24 weeks	8
Cobb angle	↑Cobb angle in EG *vs*. CG	60 min	3 days/week	12 weeks	5
Cobb angle QoL (SRS-23) Angle trunk rotation	↑Cobb angle, and trunk rotation	90 min	3 days/week	24 weeks	6
Cobb angle (Lumbar and thoracic) QoL (SRS-22) Angle trunk rotation (lumbar and thoracic)	↑Cobb angle, QoL, and trunk rotation in EG *vs*. CG	90 min	3 days/week	10 weeks	8
Cobb angle Angle trunk rotation	↑Cobb angle and trunk rotation in EG *vs*. CG	60 min	3 days/week	24 weeks	7

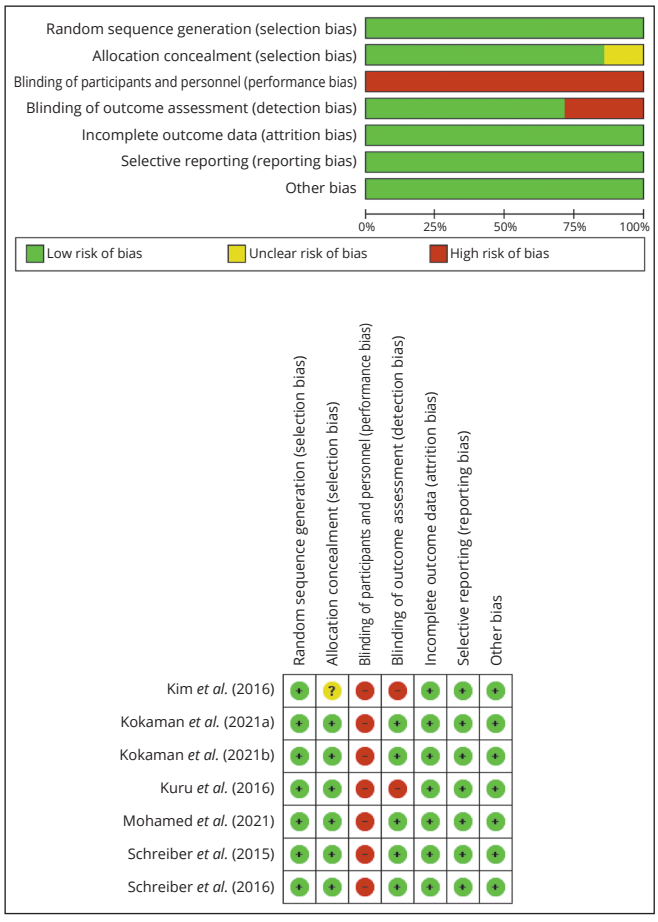

Figure 2.—Risk of bias Cochrane tool.[14, 26-30]

risk ratio crossed the null value, when the sample sizes were <50 individuals and two levels when the sample sizes were ≤30 individuals).[20, 21]

Data synthesis and analysis

The quantitative synthesis of the results was carried out according to the outcomes considered: Cobb angle, QoL, and trunk rotation angle. When studies used different tools to assess the same outcome, the authors performed inverse variance methods.

Three different meta-analyses were performed for the Cobb angle, angle of trunk rotation, and QoL. To perform the meta-analysis, the mean difference (MD) in final scores and standard deviations (SDs) were used to perform the meta-analysis. SMD and 95% CI were calculated based on the post-intervention means and SDs.

Significance was set at a P value <0.05. Statistical heterogeneity was assessed using the inconsistency measure (I^2). Fixed or random effects models were used according to the degree of heterogeneity, which was assessed using the I^2 coefficient. If I^2 was greater than 50%, indicated heterogeneity, and random effects models were used, and when I^2 was less than 50%, fixed effect models were used.

Data on outcomes of interest were extracted by a researcher using RevMan 5.4 software.

Evidence acquisition

Literature search and screening

Six studies were included in the qualitative synthesis. The description of the selection process is shown in the PRISMA flowchart diagram (Figure 1). Ten studies were assessed for eligibility, but the study of Shah *et al.*[22] was excluded for conference abstract, Gao *et al.*[23] study design was not an RCT, and the studies of Schreiber *et al.*[24, 25] were excluded for not presenting the outcomes of interests. The agreement between reviewers was calculated by kappa, with a value of 0.86.

Characteristics of eligible studies

A total of six RCTs were included, comprising 144 patients. The sample size ranged from 14 to 42 patients.

All the studies included patients between 10 and 18 years old diagnosed with AIS with a Cobb angle above 10º, and a Risser sign between zero and five.[14, 26-30] The sociodemographic and clinical characteristics of the participants in each study are shown in Table I.

The intervention group in each trial received Schroth exercises.[14, 26-30] The interventions in the control group varied among the studies. Three studies applied no intervention or standard care in the control group,[14, 26, 29] one applied Pilates,[28] one used core stabilization exercises,[30] and one applied proprioceptive neuromuscular facilitation (PNF).[27]

The duration of the sessions, the number of sessions per week, and the total number of sessions are presented in Table I. The sessions ranged from 30 to 90 minutes, the most common frequency was three sessions per week, and most of the studies performed a two to six months intervention.

Outcome measures

The outcomes considered in this systematic review and meta-analysis were the Cobb angle, QoL, and trunk rotation angle. All the studies assessed the Cobb angle using X-rays in the anterior-posterior direction in a standing position to measure the degree of scoliosis.[14, 26-28, 30] Three studies assessed QoL

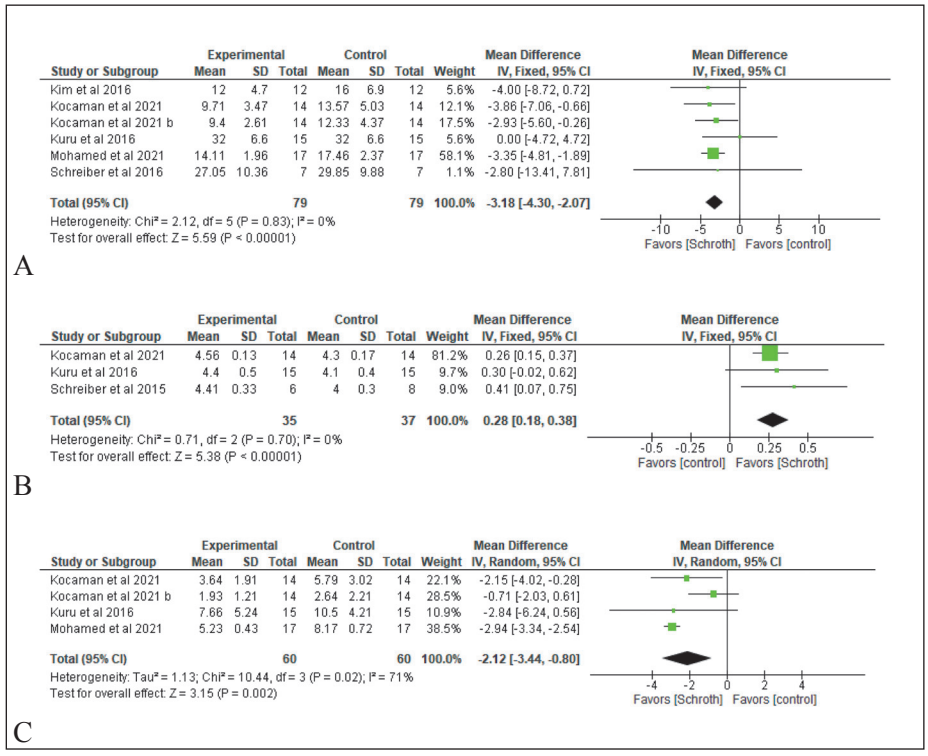

Figure 3.—A) Forest plot of Cobb angle; B) forest plot of QoL; C) forest plot of trunk rotation angle.[14, 26-30]

using the Scoliosis Research Society (SRS) 22[29, 30] or 23.[26] Three studies assessed trunk rotation angle with a scoliometer.[26, 27, 30] All the studies assessed the outcome variables at baseline and after the intervention (short-term), and no follow-up periods were considered in any study.

Study quality and risk of bias

All RCTs included in this review did not blind participants and personnel. Non-pharmacological conservative trials struggle to be blinded because the therapist cannot be blinded from what they are using as treatment. The difficulty with blinding is largely recognized and for that reason, Furlan *et al.*,[31] recommended successful blinding if the assessor was perfectly blinded. Four studies blinded the examiners that performed the assessment.[14, 27, 29, 30] The Cochrane risk-of-bias tool results are shown in Figure 2.[14, 26-30]

According to the PEDro Scale two studies presented fair quality,[26, 28] and four presented high quality.[14, 27, 29, 30]

Synthesis of results

Cobb angle

Cobb angle was measured in five studies.[14, 26-28, 30] All the studies were included in the quantitative synthesis, and meta-analysis showed that Schroth exercises produce significant improvement in Cobb angle compared to no intervention or other conservative treatments in the short-term (mean difference (MD) = -3.18º; 95% CI: -4.30, -2.07; I^2: 0%) (Figure 3A).

QoL

QoL was measured in three studies.[26, 27, 29] All the studies were included in the quantitative synthesis, and meta-analysis showed that Schroth exercises produce significant improvement in QoL compared to no intervention or other conservative treatments in the short-term (MD=0.28; 95% CI: 0.18, 0.38; I^2: 0%) (Figure 3B).

Trunk rotation

Trunk rotation angle was measured in three studies.[26, 27, 30] All the studies were included in the quantitative synthesis, and meta-analysis showed that Schroth exercises produced significant improvement in trunk rotation angle compared to no intervention or other conservative treatments in the short-term (MD=-2.12º; 95% CI: -3.44, -0.80; I^2: 71%) (Figure 3C).

The quality of the evidence assessed, according to the

GRADE Evidence Profiles, showed an overall quality of evidence rated as low for the Cobb angle and very low for QoL and trunk rotation angle (Supplementary Digital Material 3: Supplementary Table I).

Discussion

The present systematic review and meta-analysis assessed the effects of the Schroth method in isolation with other conservative treatments or no treatment on Cobb angle, QoL, and trunk rotation angle in AIS patients in the short-term. Only six RCTs met all the eligibility criteria defined for this study. The results of our study showed positive results for the Schroth method in the Cobb angle, QoL, and trunk rotation angle compared to no intervention or other conservative treatments.

Two systematic reviews and meta-analyses have been found to date.[15, 16] The aim of these previously published studies was to analyze whether the Schroth method was effective for improving the Cobb angle and QoL. Both studies carried out a systematic review and included all studies that applied the Schroth method in isolation or in combination with other treatments. However, this is the first study that analyzed the effects of the Schroth method as an isolated intervention. Thus, the results of this study are in agreement with previous systematic reviews and meta-analyses that found that the Schroth method seems to reduce the Cobb angle and improve the QoL in AIS.

The Cobb angle is the most frequently used outcome for AIS. Orthopedic surgeons and physical therapists use this angle to diagnose AIS and to set intervention goals, and monitor the status of the patients.[32] Normally, therapists describe a 5º threshold as a clinically relevant Cobb difference for improvement or deterioration.[33, 34] According to the results found in this study (MD=-3.18; 95% CI: -4.30, -2.07; I^2: 0%) and previous systematic reviews and meta-analyses, the Schroth method may reduce the Cobb angle.[15, 16] But the mean difference observed in our study was insufficient to achieve the clinically relevant threshold. Despite the fact that the Cobb angle is not a patient-related outcome, the reduction of this angle is related to other variables, such as postural abnormality, cosmetic trunk deformity, column flexibility, erector spine muscles, lumbar pain, and respiratory function.[35] Furthermore, Cobb angle improvement reduces surgical needs.[16] However, it is essential to consider the duration of treatment, the frequency, and the duration of the individual sessions to establish guidelines. Park *et al.* found a medium effect size in interventions lasting less than six months and large effect sizes (≥0.08) in treatments lasting more than six months. In our study, two studies applied interventions for two to three months,[28, 30] and four RCTs applied an intervention that lasted at least six months.[14, 26, 27, 29] Concerning the frequency and duration of the sessions, all the included studies were more homogeneous. The frequency of treatment used in most of the studies was three treatments a week, and the duration of the sessions were between 30 to 90 minutes. Therefore, the existing discrepancy in the duration of the interventions should be evaluated to determine the optimal minimum duration necessary for the Schroth exercises to be effective.

AIS is associated with psychological and physical dysfunctions that can impair and reduce QoL.[36, 37] QoL is a patient-related variable quantified using different questionnaires, such as the SRS-22 or 23. These QoL questionnaires contain five domains: function, pain, mental health, self-image and satisfaction. The minimum clinically important difference has been investigated in the pain domain (0.20), activity (0.08) and appearance (0.98), but not for the total score.[38] Only three of the six studies assessed QoL using SRS-22 or 23, and only one presented the scores of the different domains.[29] The results of our study showed that the Schroth method was effective for improving QoL and this may exceed the minimum clinically important difference in AIS. The improvement in QoL could be related to the changes in subjective variables measured with the SRS-22 and SRS-23 questionnaires, such as pain and self-image,[29] but it may also be related to changes in the Cobb angle because of its relationship with respiratory capacity or postural abnormality.[39, 40] In addition, Cobb angle reduction improves perspectives regarding the need for future treatments.[41] The studies that assessed QoL performed interventions between 10 and 24 weeks,[26, 29, 30] and all obtained positive effects. However, more studies should be carried out assessing medium- and long-term follow-ups and applying different intervention times to provide more detailed evidence for the Schroth method in patients with AIS.

The trunk rotation angle was measured in three studies.[26, 27, 30] The Schroth method showed a significant improvement in trunk rotation angle compared with other conservative treatments. Some authors suggested that a decreased trunk angle may result in greater spinal stability and a reduced possibility of curve progression.[42, 43] In addition, changes in the trunk rotation and rib cage improved respiratory function.[44] The trunk rotation and the Cobb angle are considered the main clinical and prognostic indicators of curve progression.[45] The application of the Schroth method in isolation has shown improvements in both angles in patients with AIS.

Limitations of the study

This systematic review and meta-analysis has some limitations. Our search strategy may have been limited by the omission of other databases, such as SportDiscus, and we may have missed relevant articles. The inclusion of patients aged between 10 to 18 years old with Cobbe angle > 10º and Risser signs between zero and five could increase the heterogeneity of the study population, which could mean that the patients presented different risks of progression. The heterogeneity found in treatment duration complicates the interpretation of our results. Further methodological limitations, such as the insufficient sample size that could overestimate the results and the lack of follow-up measurements of the studies. PSSE that have evolved from the Schroth method have not been considered in this study, so other research on these methods which may have been omitted. Future studies should describe the total number of sessions and the duration of the intervention to allow replicability and comparison of the study. Finally, the combination of therapies that produce the best effects should be investigated, as well as their doses.

Conclusions

The application of the Schroth method in isolation is effective for reducing the Cobb angle and the trunk rotation angle and for improving the QoL after the intervention compared to no intervention or other conservative therapies in patients between 10 and 18 years old diagnosed with AIS, but the improvement in Cobb angle did not exceed the minimum clinically important difference. Further investigation is needed to determine the medium- and long-term effects in patients with AIS and to determine the best multimodal intervention.

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