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Effectiveness of Physiotherapeutic Scoliosis-Specific Exercises Versus General Exercises in Adolescent Idiopathic Scoliosis: A Systematic Review and Meta-Analysis

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Abstract

Introduction: The effectiveness of physiotherapeutic scoliosis-specific exercises (PSSE) over general exercises (GE) in adolescents' idiopathic scoliosis (AIS) is a topic of much debate.

Method: PubMed, Scopus, Cochrane, Embase, and PEDro databases were systematically searched for studies comparing PSSE versus GE and reported the outcomes of Cobb angle (CA), Anterior Trung Rotation (ATR), and Quality of life (QoL). Mean differences (MD) and 95% confidence intervals (CI) were pooled using a random- effects model. Heterogeneity was examined with I2 statistics.

Results:We included 6 RCTs and 3 observational studies with 749 patients with AIS, of whom 442 (59.1%) patients received PSSE therapy and 307 (40.9%) were assigned to GE. The mean age was 13.57 years. Mean follow-up ranged from 3 to 54 months. Risser signs 0-5. PSSE significantly reduced Cobb angle (MD -3.10˚; 95%CI [- 5.55,-0.66]; I2=91%; p=0.01) and ATR (MD -2.13˚; 95%CI [-3.05, -1.22]; I^2=89%; p<0.001) as compared with GE. There was no statistical difference between groups in QoL analyzed by the Scoliosis Research Society Questionnaire 22 total score (MD 0.06˚; 95%CI [-0.21, 0.34]; I^2=88%; p=0.64).

Conclusions: These findings suggest that PSSE promoted a higher reduction in Cobb angle and ATR than GE in patients with AIS without a significant impact in QoL.

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INTRODUCTION

Idiopathic scoliosis is a three-dimensional spinal deformity with an unknown etiology characterized by a lateral deviation in the frontal plane, an axial rotation in the horizontal plane, and an abnormal curve in the sagittal plane (1). Scoliosis can develop at any age, but it appears more in periods of rapid growth, including the first 6-24 months of life, between 5 and 8 years, and with a high growth point in puberty, approximately around the age of 11-14 years (2,3,4). According to the Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT), the global incidence of adolescent idiopathic scoliosis (AIS) is around 0.93%-12.0% (5). Women are more affected (6), at a rate of 10:1 as compared with men (7).

According to SOSORT, the physiotherapeutic scoliosis-specific exercises (PSSE) should be based on 3D correction. PSSEs have in their foundation the 3-dimensional correction of the posture, the stabilization of the corrected posture, the education of the patient, and the integration of these positions in daily life activity (5).

However, the PSSEs are complex, require training, and are not widely adopted, which limits their scientific validation. Prior meta-analyses have shown that PSSE is superior to general exercises in reducing Cobb angle, and angle of trunk rotation (ATR) (8,9). However, these prior meta-analyses included studies comparing PSSE therapies versus standard care or observation therapies, which limits the direct comparison of PSSE versus other active therapies. Also, the prior meta-analysis did not include the novel PSSE- Schroth therapy (10). Therefore, we performed an updated systematic review and meta- analysis to compare two active therapies - PSSE versus general exercises in patients with idiopathic scoliosis (IS).

METHODS

The systematic review and meta-analysis were performed and reported following the Cochrane Collaboration Handbook for Systematic Reviews of Interventions and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Statement guidelines (11,12). This systematic review with meta-analysis was registered in the International Prospective Register of Systematic Reviews (PROSPERO; CRD42024576432).

Study eligibility

We included studies that met the following eligibility criteria: (1) peer-reviewed RCTs or observational studies; (2) comparing PSSE versus GE; (3) in adolescents with AIS aged 10-18 years old; (4) reporting at least one of the clinical outcomes of interest; and (5) studies with population meeting at least one the following AIS diagnostic criteria: use of braces, Risser stage 0-5, and a Cobb angle between 10-45 degrees. We excluded studies with (1) patients already receiving other active therapies at the same time with PSSE; (2) no outcomes of interest; and (3) an overlapping patient population with a larger study. There were no restrictions concerning the date or language of publication.

Search strategy and data extraction

MEDLINE, Cochrane, Scopus, Embase, and PEDro databases were searched from inception to August 4, 2024. The keywords used included: ("Adolescent Idiopathic Scoliosis" OR AIS OR ((Scoliosis[mh] OR "Idiopathic Scoliosis") AND adolescent*)) AND (PSSE OR "Physiotherapeutic scoliosis-specific exercises" OR Schroth OR PSSE-Schroth OR "Barcelona Scoliosis Physical Therapy School" OR BSPTS OR "side shift" OR lyon OR "Functional Individual Therapy of Scoliosis" OR FITS OR "Scientific Exercise Approach to Scoliosis" OR SEAS OR fed OR dobomed) AND ("general exercise*" OR "core exercise*" OR ((stabilization OR stabilization) AND (core OR trunk OR neurodynamic)) OR "conventional therapy" OR "muscle strengthening" OR "stretching" OR "usual therapy" OR pilates).

We extracted data for (1) Cobb angle; (2) trunk rotation; and (3) Quality of life (QoL) assessed by the SRS-22 questionnaire. All articles were systematically assessed using the pre-specified inclusion and exclusion criteria. Three reviewers (between L.S., M.P., and Y.Y) undertook the article selection and data extraction independently. Disagreements were resolved by consensus.

Quality assessment

The Cochrane tool for assessing risk of bias in randomized trials (RoB 2) was utilized for the quality assessment of randomized studies (13). The ROBINS-I was used for assessing the risk of bias in observation studies (14). Three authors (L.S., Y.Y, and M.P.) independently evaluated the risk of bias. Disagreements were resolved by consensus between authors. We explored the potential for publication bias by visually examining the funnel plots for the primary efficacy and safety endpoints.

Data analyses

Treatment effects for continuous outcomes were analyzed using mean difference (MD) with 95% confidence intervals. Heterogeneity was examined with Cochran's Q test, I^2 statistics, and Tau-square using the DerSimonian and Laird estimator. Heterogeneity was reported as low (I^2=0–25%), moderate (I^2=26–50%), or high (I^2>50%). The random- effects model was used in all studies. All statistical analyses were performed using Review Manager statistical software.

RESULTS

Study selection and baseline characteristics

Our systematic search yielded 377 potential articles. (Figure 1) follows the PRISMA for study selection (11). After removing duplicates and excluding articles based on title or abstract, 36 studies were retrieved and reviewed in full for possible inclusion. Finally, 6 RCTs and 3 observational studies met all inclusion criteria and were included in our meta- analysis (10, 15-22). We included 749 patients, with 442 (59.1%) patients assigned to PPSE therapy and 307 (40.9%) assigned to GE. The mean age was 13.5 years and 615 (82.1%) patients were women.

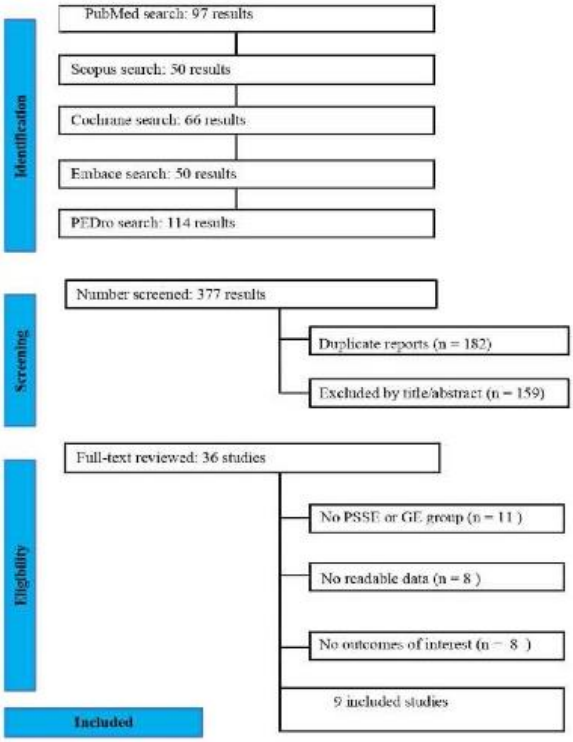


Figure 1. PRISMA flow diagram of study screening and selection

Table 1 summarizes the baseline characteristics of the included studies. Table 2 summarizes the study design, endpoint definition, and key findings of each included study.

Table 1. Basic characteristics of the studies selected

Study	Design	Number of patients I/C	Female I/C	Age I/C	Cobb angle initial I/C	Follow Up
Mohamed 2021	RCT	17/17	100%/100%	14.50±1.20 14.9±1.40	20.42±2.57 20.21±2.80	6 Months
Kocaman 2021	RCT	14/14	71.4%/78.5%	14.7±2.37 14.21±2.19	17.64±4.01 17.29±3.45	10 Weeks
Kim 2016	RCT	12/12	100%/100%	15.60±1.1 15.3±0.8	23.6±1.5 24.0±2.6	12 Weeks
Monticone 2014	RCT	55/55	70.9%/74.5%	12.5(1.1) 12.4(1.1)	19.3(3.9) 19.2(2.5)	54 months
Noh Koog Dong 2014	Observational	16/16	75%/87.5%	13.8(2,8) 14.9(2.3)	21.6±10.1 19.0±7.0	30 session
Karavidas 2024	Prospective Control Study	153/58	96.7%/93.1%	12.6 13.1	20.8(15-25) 19.4(15-25)	Mean 29.4 months
Negrini 2019	Observational Study	145/95	71%/80%	12.07(1.05) 12.07(1.07)	15,36 ± 2.67 15.38±2.62	28 months
Moubarak 2022	RCT	15/15	60%/66.6%	12.03(1.94) 11.5(1.58)	19.06±2.62 18.76±3.57	12 weeks
Yagci 2019	RCT	15/15	100%/93.3%	14.2(1.5) 14.0(1.3)	27.6±8.0 30.0±9.3	4 months

Values are presented as mean ± standard deviation, number (%), or range; C: control group; I: intervention group; RCT: randomized controlled trial.

Table 2. Characteristics of the studies included in the meta analysis

Authors and publication Year	Baseline Characteristics	Intervention details	Variables measured	Key findings
N. Karavidas et al., 2024	Age >10 years old Risser sign of 0-2 -Cobb angle of 10-25 degrees ATR >5 with a high risk of progression	1. The PSSE-Schroth group received PSSE exercises 1 time /week for 55 min and were advised to exercise at home 5 times/week for 30 min 2. General or no exercises	-Cobb angle (CA) to measure the curve magnitude of the spine. -The angle of trunk rotation (ATR) was measured using the scoliometer-Scoliosis Research Society-22 (SRS-22) questionnaire to assess health-related quality of life -Trunk Appearance Clinical Evaluation (TRACE), for body symmetry assessment - TAPS questionnaire Compliance%	-In the PSSE-Schroth group 63.2% remained stable, 23.9% improved, 12.9% worsened. The mean difference reached statistical significance for Cobb L/TL (p=0.02) but not for Cobb angle Th p=0.08). Only 16 subjects prescribed a brace. The success rate was 87.1%(p=0.002) -A significant decrease on ATR Th with mean 5.9˚, p=0.04 and ATR L/TL mean 5.5˚, p=0.05. -TRACE score improved from 6.3 to 4.6 (p=0,04). -On the SRS-22 overall score, a statistically significant improvement was observed: 90.3, p=0.008; mental health 20.6, p=0.005; self-image 21.4, p=0.03. Improvement without statistical significance on pain 23.6, p=0.06; Satisfaction was excellent. -TAPS with p=0.03. On the control group 25.9% were stable, 74.1% warsened and 39 subject required brace (p=0.003). -A fully compliance analysis showed a sucses rate 94.8% as 53.8% remained stable, 41%improved 7,7% worsened. p=0.02 Moderate compliance showed 75.9% remain stable, 13% improved, 11.1% progresed p=0.05. Poor compliance 64.4% remaned stable, 0% improved and 35.5% progresed.
H. Kocaman et al., 2021	- Adolescents idiopathic scoliosis Aged 10-18	-Schroth group (SG): Performed Schroth + traditional	1. Primary outcome: Cobb angle 2. Secondary outcomes:	Cobb Angle Thorasic and lumbar Improvement: The Schroth group showed greater improvement than the core

	years - Risser stage < 3 - Cobb angle between 10-30 degrees - No history of other medical conditions - No prior treatment for scoliosis - 21 females, 7 males	exercises 90 min, 3 times/week -Core group Performed core stabilization (CS) exercises and traditional exercises, 90 min, 3 times/week	- Trunk rotation angle (ATR) - Cosmetic trunk deformity (WRVAS) - Spinal mobility (Spinal Mouse) - Health-related quality of life (SRS-22 questionnaire)- Peripheral muscle strength (Biodex dynamometer)	group with a statistically significant p-value of <0.001. Thoracic Trunk Rotation Angle: Similar to the Cobb angle, the Schroth group had a significant improvement over the core group (p<0.001), but no significant group by time on ATR Lumbar p=0.302 Cosmetic Trunk Deformity: The Schroth group demonstrated significant enhancement in cosmetic trunk deformity (p<0.001). Quality of Life (SRS-22): The Schroth group reported significant improvements in quality of life (p<0.001). Peripheral Muscle Strength: The core group showed greater improvement in peripheral muscle strength with a significant p-value of <0.001 compared to the Schroth group.
R.A. Mohamed et al., 2021	- Adolescents aged 14-16 years old. - Cobb angle <25 degrees. - Risser sign of 2-5. - No other treatments that could affect scoliosis.	-Schroth exercise group - Patients received the Schroth 3D exercise for 1 hour, 3 times/week. -The proprioceptive neuromuscular facilitation (PNF) group received PNF for 1 hour, 3 times/week.	1. Cobb angle (measured by x-ray) 2. Angle of trunk rotation (measured by scoliometer). 3. Static plantar pressure distribution. 4. Functional capacity. 5. Adherence rate.	-Post-treatment comparison between SG and PNF group revealed significant differences with superior affect to the Schroth group (p<0,001) on Cobb angle, ATR, Static plantar pressure and 6 minute walk test (6MWT). -Adherence rate 98%
E.E.S.Moubarak et al., 2022	- Adolescents with mi ld idiopathic scoliosis. Age10-14 years. - Cobb angle	-The Core stabilization group, 60 min, 3 times/week and 20min at home.	-The Cobb angle -Back mus cle endurance -ATR	-The post-treatment results revealed a significant difference in Cobb angle (p<0.001), ATR (p<0.001), and Total score of SRS-22(p<0.05) in favor of the CS group

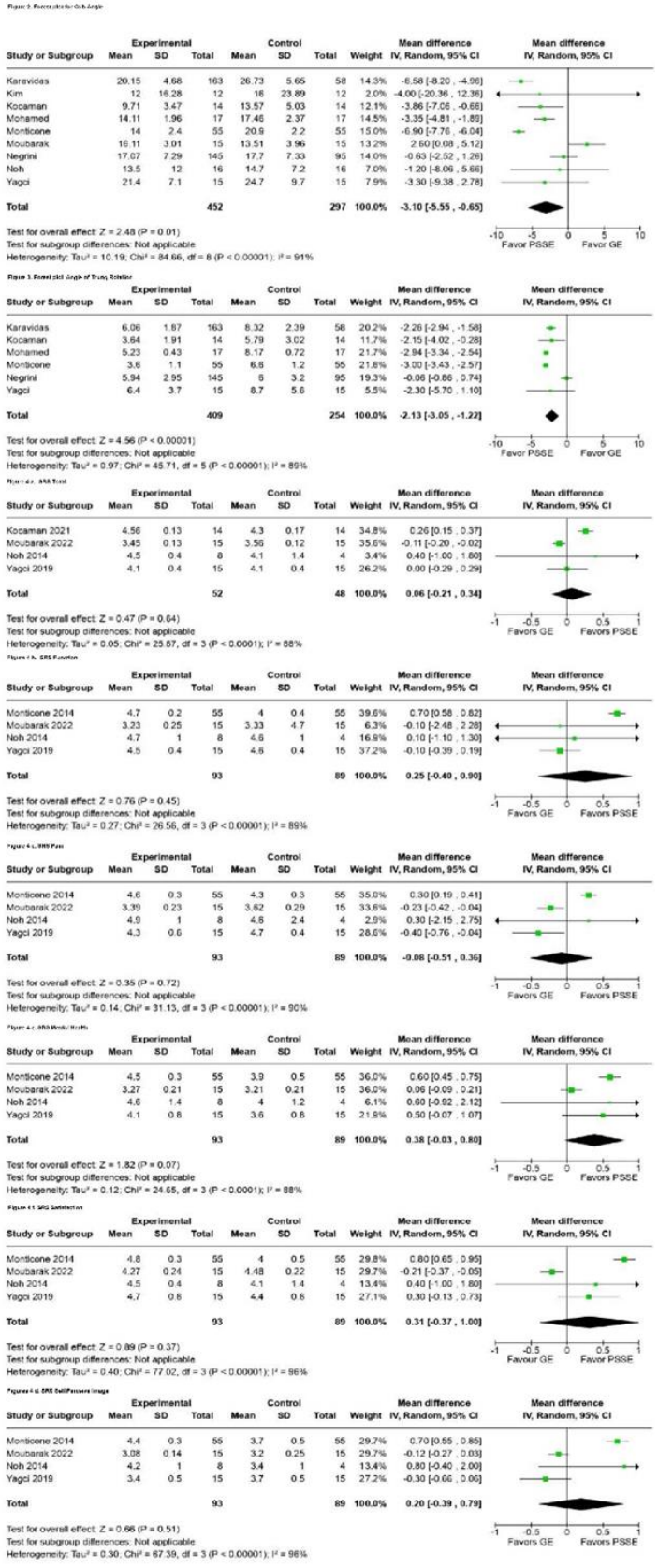
	10-20 degres -Risser <2	-The Active self-correction (ASC) exercises, 60 min, 3 times/week and 20 min at home	-Quality of life using SRS-22 Video compliance	- No significant difference in self-image and mental health between groups (p>0.05).
M.Montione et al., 2014	- Primary diagnosis AIS. -Cobb 10-25 degrees. -Risser sign < 2 -Age > 10 years	The intervention group ASC for 60 min , 1 time/week 30 min, times/week home. - The control group received general exercises for 60 min , 1 time/week and 30 min, 2 times/week at home	- Cobb angle -ATR - Scoliosis Research Society (SRS-Questionnaire quality of life - Compliance	- In the experimental Cobb angle, improved in 69%, (decreased <3˚), worsened 8% (increase >3˚) and remained stable. The change after training was -5.3 (p<0.001) -In the control group, improved, 39% worsened and 55% remained stable. The mean change after training was (p<0.001) -The mean change in ATR the ASC group after training was -3.5. (p<0.001) In the control group the ATR remained stable. (p<0.001) -Significant improvements the experimental group on SRS-22 with post-training >0.75 for all the (p<0.001) -No significant changes were observed on the control group The subgroup <13 years on ASC group exhibited a mean change -4.9. (p<0.001), whereas a mean change of -5.8 for subjects >13 years.. (p<0.001) In the ASC group 71% improved, 9.7% worsened and 19.3% remained stable. In the control group 9.4% improved, 31.2% worsenedand 59.4% remained stable at age <13 years. In the ASC group 66.7% improved, 4.8 % worsened and 28.5% remained stable. In the control group 0% improved,

				52.6% worsened and 47.4% remained stable at age <13 years
G. Yagci et al., 2019	- Adolescents idiopathic scoliosis - Cobb angle 20-45˚ -Prescription brace or conservative treatment. Risser sign 2-3 -Aged >12 years	- Core stabilization (CS) for 40 min 1 time/week and 20 min daily at home. -SEAS group for 40 min 1 time/week and 20 min daily at home Both weared brace 23h/day	-Cobb angle, - Angle of trunk rotation (ATR), -Posterior Trunk Asymetri Index (POTSI) -Walter Reed Visual Assessment Scale (WRVAS) -Quality of life (QoL) with SRS-22 Compliance	The mean decrease on cobb angle was -5.6 for CS and -5.2 gor SEAS . Compliance with the brace was 88% in CS, with 79.6% in SEAS group. Compliance with home exercises was 61.6% in CS with 63.7% in SEAS group (p= 0.78)
D.K.Noh et al., 2014	Adolescents idiopathic scoliosis -Aged 10-19 years	3 Dimentional corrective spinal technique (CST) for 60 min /day , 2-3 times /week) Concentional exercises program (CE) for 60 min /day , 2-3 times /week)	Cobb Angle Thorasic kyfosis Lumbar lordosis Sacral scope Pelvic tilt Pelvic incidence Vertebral rotation (VR) Quality of life	CST group Showed greater improvement in Cobb Angle (p=0.03) SRS-22 Score total (p=0.041) There were no significant changes in other measurement between groups.
G.Kim et al., 2016	Idiopatic Scoliosis Patients Cobb >20˚	Schoth (SG), 60 min, 3 times/week Pilates (PG), 60 min 3 times/week	Cobb angle Body distribution	The intragroup comparison showed significant efect on cobb angle for both groups (p<0.05). There was a significant difference in the total weight for SG(p<O.05), but no significant in PG(p>0.05)
S.Negrini et al., 2019	Adolescents idiopathic scoliosis - Aged >10 years Riser 0-2 Cobb angle 11˚-20˚	SEAS Group, Usual Physiotherapy Group (UG), No therapy,	Cobb angle ATR TRACE Rib hump height	Significance difference was found for cobb angles in all groups, but within the error range 5˚ Trace improved signjificantly better tha the (UG) group Significance difference was in the SEAS group for hump height.

Pooled analysis

In patients with AIS, PSSE therapy reduced Cobb angle (MD -3.10°; 95%CI [- 5.55,-0.66]; I 2 =91%; p=0.01; Figure 2). PSSE also reduced ATR (MD -2.13°; 95%CI [-3.05, -1.22]; I 2 =89%; p<0.001; Figure 3).

There was no statistical significance in total SRS-22 score (MD 0.06; 95% CI [-0.21, 0.34]; I 2 =88%; p=0.64; Figure 4a), and in the individual components of function (MD 0.25; 95%CI [-0.40, 0.90]; I 2 =89%; p=0.45; Figure 4b), pain (MD 0.08; 95%CI [-0.51, 0.36]; I 2 =90%; p=0.72; Figure 4c), self-perceived image (MD 0.20; 95%CI [-0.39,0.79]; I 2 =96%; p=0.51; Figure 4d), mental health (MD 0.38; 95%CI [-0.03, 0.80]; I 2=88%; p=0.07; Figure 4e), and satisfaction with menage (MD 0.31; 95% CI [-0.374,]; I 2 =96%; p=0.37; Figure 4f).



Quality assessment

There was no evidence of publication bias (Supplemental Figures S1-S4) in the funnel plot analysis. Egger's regression test could not be performed due to the number of included studies (<10), as per Cochrane recommendations. The most RCTs were considered at low for risk of bias according to the RoB2 tool, only Kim et al…was considered some concerns based on the domain of the randomization process (Table 3). Two Observational studies had a moderate risk of bias based predominantly on the risk of confounding factors. Only Noh et al.., had a serious risk of bias (Table 4).

Table 3. The risk of bias of randomized control study

Study	Bias from the randomization process	Bias due to deviations from intended	Bias due to missing outcome data	Bias in the measurement of the	Bias in the selection of the reported result	The overall risk of bias
Kocaman et al., 2021	Low	Low	Low	Low	Low	Low
Yagcki et al., 2018	Low	Low	Low	Low	Low	Low
Kim et al., 2016	Some concerns	Low	Low	Low	Low	Some concerns
Monticone at al., 2014	Low	Low	Low	Low	Low	Low
Moubarak et al., 2022	Low	Low	Low	Low	Low	Low
Mohamed et al., 2021	Low	Low	Low	Low	Low	Low

Legend: Risk of bias of prospective randomized controlled studies.

Table 4. Risk of bias of Observation studies

Study	Bias due to confounding	Bias in the selection of participants	Bias in the classification of interventions	Bias due to deviation s from intended interventions	Bias due to missing data	Bias in the measurement of outcomes	Bias in the selection of the reported result	The overall risk of bias judgement
Negrini et al., 2019	Moderate	Moderate	Low	Moderate	Moderate	Low	Low	Moderate
Karavidas et al., 2024	Moderate	Moderate	low	Low	Moderate	Low	Low	Moderate
Noh et al., 2014	High	Moderate	Moderate	Moderate	Low	Low	Low	Serious

DISCUSSION

This comprehensive meta-analysis of 6 RCTs and 3 observational studies enrolled 749 patients and examined the efficacy of PSSE versus general exercises in AIS. As compared with general exercises, PSSE reduced Cobb angle and ATR. In contrast, there was no difference between PSSE and GE in the outcomes SRS-22.

Scoliosis is associated with increased rates of pain, mental health issues, and reduced body image and function that, if not treated appropriately, may lead to pulmonary complications and the need for surgery (23-27). Many conservative therapies are used to stop the progression and reduce the deformity of AIS (8). However, which therapy is best for treating children and adolescents with scoliosis remains unclear. Clinical trials comparing PSSE with conventional therapy in patients with scoliosis have shown that 3D correction therapies, in association with breathing techniques, lead to better results in reducing deformity compared with general exercise (28). In our study, we focused on including studies reporting outcomes at the peak of growth, when the risk of progression is high.

Our findings favor PSSE over GE in reducing Cobb angle and ATR, which may imply their effectiveness in reducing or stopping the deformity of adolescents with idiopathic scoliosis. Despite the statistical significance, however, the angles should be analyzed in terms of clinical significance, as slight angle reductions may not imply significant clinical changes. Measurement errors can occur when assessing the Cobb angle, with a variability of up to +/- 5° (5). PSSE ultimately aims to delay or stop the progression of the Cobb angle and bracing. The success rate in achieving these favorable outcomes has been reported as 82% to 87% with PSSE, as compared with 23 to 26% in GE (10,17). Moreover, these studies have reported mild scoliosis, ages 10-18 years old, and Risser signs 0 to 3 as categories with a higher risk of progression, which may derive a stronger benefit from PSSE. In our meta- analysis, we could not perform a dedicated analysis of the success rate due to limited reporting of this outcome in individual studies.

These findings are consistent with other studies, such as Khaledi et al. (29), which show that Schroth therapy is effective in reducing the Cobb angle with a moderate level of evidence. Similarly, Burger et al. (30), suggested that Schroth exercises have a significant effect on reducing the Cobb angle with a level of evidence L2. Other studies that support our findings include those by Schriber et al. (7), Kuru et al. (31), Park et al. (32), and Seleviciene et al. (33), which demonstrate that PSSE therapies are more effective in improving deformities and enhancing the quality of life. Statistical significance showing the superiority of PSSE compared to general exercises was also reported by Karavidas et al. (10), who found that PSSE is better at improving the Cobb angle, trunk rotation, and quality of life.

Our study builds on prior meta-analysis by excluding studies not directly comparing PSSE versus GE. In the previous meta-analysis, patients in the control group received standard care or observation (8,9). We also included a study that used the PSSE Schroth technique on AIS. This new technique is focused on correction in three dimensions, corrective/rotational breathing, muscle activation, and stabilization. It brings a new classification system and a novel concept of overcorrection, fundamentally altering the patient approach (10).

According to the SOSORT guidelines, all PSSE schools should be based on 3D autocorrection, self-elongation, and patient training for activities of daily living (5). Different PSSE schools like Schroth, Lyon School, Scientific Exercise Approach to Scoliosis (SEAS), Barcelona Scoliosis Physical Therapy School (BSPTS), Side Shift, Functional Individual, Therapy Scoliosis (FITS), DoboMed, and FED (Fixation, Elongation, Derotation) are focused in the treatment of AIS (34). More recently, a method was developed as a new PSSE school and PSSE-Schroth (10). All those schools use PSSE but their methodology, classification, and frequency are different (8). Regarding general exercises, many therapies are used also like, core muscle, pilates, and conventional therapies. These differences may in part explain the high heterogeneity of our findings.

PSSE is designed specifically for scoliosis, focusing on the three-dimensional nature of the spinal deformity. These exercise aim to address specific curve patterns, improve postural alignment, and reduce asymmetries, directly influencing quality of life domains, such as self-image and function in the SRS 22. By correcting visible asymmetries and improving posture, PSSE can enhance self-esteem and body image, critical components of the self-image, and mental health domains in the SRS-22. Nevertheless, we did not find a statistically significant improvement in the of quality of life between the PSSE group and the general exercise group. These results may have been driven by the high heterogeneity, low sample size, and null results in some of the included studies.

PSSE integrates breathing techniques, muscle activation, and functional movements, which can reduce discomfort, improve lung capacity, and enhance physical function. These benefits contribute to higher scores in the function/activity and pain domains. PSSE programs are customized to each patient's specific curve type and severity, making the exercises more effective compared to GE, which does not address the particular biomechanics of scoliosis. PSSE emphasizes active participation, teaching patients how to manage and maintain their condition. This fosters a sense of control and contributes to better outcomes in the mental health domain of the SRS-22. PSSE not only aims at curve stabilization but also at improving overall spinal health and preventing progression. This long-term focus can result in sustained improvements in quality of life compared to GE.

Our study has limitations. First, the inclusion of observational studies prompts the analysis for confounding factors and bias. Second, the study is limited by a small sample size and a short follow-up period, and null results may be due to a lack of power. Third, the definition and type of exercises applied in the PSSE and the GE groups were not homogeneous across studies. Fourth, due to the absence of patient-level data, we were unable to assess the impact of key factors, such as treatment adherence, the proportion of patients using braces, and the percentage of clinically significant angle changes (e.g., changes exceeding 5º).

This study highlights the need for adequately powered randomized studies to analyze the efficacy of PSSE therapies in a longer follow-up period.

CONCLUSION

In this meta-analysis of 6 RCTs and 3 observational studies including 749 patients with AIS. PSSE therapy is associated with a statistically significant reduction in Cobb angle and ATR compared to GE, albeit with a small magnitude of improvement, falling short of a threshold of substantial clinical benefit.

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Conflict of Interest Statement: The authors affirm that there are no conflicts of interest related to this work.

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