International Journal of Innovative Technology and Interdisciplinary Sciences
https://journals.tultech.eu/index.php/ijitis
ISSN: 2613-7305
Volume 9, Issue 2
DOI: https://doi.org/10.15157/IJITIS.2026.9.2.1217-1240
Received: 29.01.2026; Revised: 13.05.2026; Accepted: 11.06.2026

Research Article

A Feedback-Oriented Perspective on Schroth-Based Scoliosis-Specific and General Exercises for Pain and Quality of Life in Adolescents with Idiopathic Scoliosis: A Randomized Controlled Trial

Enkeleda Sinaj [1]*, Luljeta Stanaj[2], Vjollca Ndreu[1], Fatjona Kamberi[3]

[1]Faculty of Medical Technical Science, University of Medicine Tirana, Tirana, Albania
[2]Trauma University Hospital, Tirana, Albania
[3]Faculty of Health, "Ismail Qemali" University of Vlora, Vlora, Albania
***enkeleda.sinaj@umed.edu.al**

Abstract

Adolescent Idiopathic Scoliosis (AIS) is a three-dimensional spinal deformity associated with pain, altered self-image, and reduced health-related quality of life (HRQoL). While general exercises (GE) are commonly prescribed, they do not specifically address the three-dimensional characteristics of the deformity. Physiotherapeutic Scoliosis-Specific Exercises (PSSE), particularly the Schroth method, aim to correct postural asymmetry, vertebral rotation, and breathing dysfunction through individualized interventions. This prospective randomized controlled trial compared the effects of a structured Schroth-based PSSE program with GE on pain and HRQoL in adolescents with AIS. Eighty participants (56 females, 24 males; mean age 14.3 ± 2.1 years) were randomly assigned to PSSE-Schroth (n = 40) or GE (n = 40), with 66 completing the 12-month intervention. Both groups participated in supervised physiotherapy and home-based exercise programs. Outcomes were assessed at baseline and post-intervention using the Scoliosis Research Society-22 (SRS-22) questionnaire, and appropriate statistical analyses were applied. Significant improvements were observed in all SRS-22 domains in both groups ($p \leq 0.001$). The PSSE-Schroth group demonstrated larger effect sizes and significantly greater improvements in self-image and mental health compared to GE ($p = 0.018$), while pain and functional outcomes improved in both groups with greater clinical gains in the PSSE group. These findings indicate that although both interventions are effective in improving pain and HRQoL in adolescents with AIS, Schroth-based PSSE provides superior benefits, particularly in psychosocial domains, supporting its integration into conservative management strategies. From a feedback-oriented perspective, these results may reflect enhanced sensorimotor integration and postural control mechanisms associated with scoliosis-specific exercises.

Keywords: Adolescent Idiopathic Scoliosis; Physiotherapeutic Scoliosis-Specific Exercises; Postural Control Mechanisms; Interventions.

INTRODUCTION

Adolescent Idiopathic Scoliosis (AIS) is a structural, three-dimensional deformity of the spine with an unknown etiology that typically develops during the adolescent growth spurt. Epidemiological studies estimate that AIS affects approximately 2–3% of adolescents and occurs more frequently in females than in males [1, 2]. Beyond the spinal deformity, AIS is associated with a range of physical and psychosocial consequences, including pain, reduced physical function, and concerns related to body appearance, which may negatively influence emotional well-being and participation in daily activities [1, 3]. Health-related quality of life (HRQoL) has therefore become an essential outcome in scoliosis research. The Scoliosis Research Society-22 (SRS-22) questionnaire is the most widely used disease-specific instrument for assessing HRQoL in patients with idiopathic scoliosis. It evaluates five domains: pain, function, self-image, mental health, and satisfaction with treatment [4]. Previous studies have demonstrated that the SRS-22 has strong reliability and sensitivity to clinical change, and minimal clinically important differences (MCID) have been established for several domains, supporting its use in clinical trials [3-6]. The optimal conservative treatment strategy for improving HRQoL outcomes in AIS remains a subject of ongoing debate [7].

General exercise programs are commonly prescribed to improve overall physical fitness, muscle strength, flexibility, and postural control; however, they do not specifically address the three-dimensional characteristics of the scoliotic deformity [8]. In contrast, Physiotherapeutic Scoliosis-Specific Exercises (PSSE) represent specialized rehabilitation approaches designed to correct spinal deformity through individualized three-dimensional postural correction, neuromuscular training, and breathing techniques adapted to the patient's curve pattern [9–11]. International guidelines developed by the Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT) recommend PSSE as a key component of conservative management during growth [9]. A growing body of evidence has demonstrated the effectiveness of scoliosis-specific exercise programs. Randomized controlled trials have reported improvements in spinal curvature, trunk asymmetry, and patient-reported outcomes following Schroth-based interventions [11–18]. Furthermore, systematic reviews and meta-analyses have suggested that PSSE may contribute to reductions in Cobb angle and improvements in HRQoL outcomes [7, 19–23]. However, much of the existing literature has primarily focused on radiological outcomes, while psychosocial dimensions particularly self-image and mental health remain comparatively underexplored. In addition, many studies have been limited by short- or mid-term follow-up durations, and relatively few trials have directly compared PSSE with general exercise programs as an active clinical comparator [12, 16, 24].

In recent years, the Schroth method has undergone further clinical development beyond its classical form, incorporating advances in neuromuscular control, individualized progression strategies, and functional integration into daily activities. This contemporary evolution, as described by Karavidas and colleagues [11], aims to enhance both biomechanical correction and psychosocial adaptation. Despite these advancements,

empirical evidence evaluating such modern adaptations within a randomized controlled framework remains limited.

Contribution and Positioning vs State-of-the-Art

Despite the growing body of literature supporting PSSE (Table 1) several important gaps remain in the current state of the art. Existing studies have predominantly focused on radiological outcomes such as Cobb angle, whereas psychosocial outcomes, particularly self-image and mental health, have received comparatively less attention [7, 19–22]. Furthermore, most randomized trials have been conducted over shorter durations and often lack direct comparison with general exercise programs as an active comparator [12, 16, 24]. In addition, evidence from Southeastern Europe remains limited, highlighting the need for region-specific clinical data. Within this context, the present study provides several specific contributions. First, it offers a long-term randomized controlled comparison between a structured PSSE-Schroth program and a general exercise intervention, addressing the lack of clinically relevant active comparator studies. Second, the study quantifies treatment effects across all SRS-22 domains using effect sizes and minimal clinically important difference (MCID) thresholds, enabling a more precise evaluation of clinical relevance beyond statistical significance. Third, the findings identify self-image as a key domain demonstrating both statistically significant and clinically meaningful improvement, suggesting its central role in the psychosocial response to scoliosis-specific rehabilitation. Importantly, this study contributes to the conceptual understanding of PSSE by supporting a multidimensional interpretation of treatment effects, in which biomechanical correction, neuromuscular adaptation, and psychosocial processes interact to influence patient-reported outcomes. In particular, the observed results are consistent with a mechanism in which improvements in self-image may act as a central driver of mental health outcomes.

Additionally, this study provides novel clinical evidence from a Southeastern European population, contributing to a more geographically diverse evidence base. Taken together, these contributions position the present study not only as a comparison between PSSE and general exercise but as an analytically grounded investigation that advances both the clinical and conceptual understanding of scoliosis-specific rehabilitation. To address the identified gaps, the present study aimed to compare the effects of a structured twelve-month Physiotherapeutic Scoliosis-Specific Exercise (PSSE-Schroth) program with a General Exercise (GE) program in adolescents with idiopathic scoliosis. The primary outcome was pain assessed through the SRS-22 questionnaire, while additional HRQoL domains were also evaluated.

Based on the existing literature, the following hypotheses were formulated:

- H1: Both PSSE-Schroth and general exercise interventions will lead to statistically significant improvements in SRS-22 domains; however, PSSE-Schroth will demonstrate greater effect sizes (Cohen's $d \geq 0.8$) in psychosocial domains.
- H2: The PSSE-Schroth intervention will produce clinically meaningful improvements (≥ MCID thresholds) in mental health and self-image domains compared with general exercise.

- H3: The overall improvement in HRQoL will be greater in the PSSE-Schroth group, although total score differences may be attenuated due to multidimensional outcome aggregation.

Table 1. State-of-the-art studies on exercise-based interventions in adolescents with idiopathic scoliosis

Study	Study design	Sample (n)	Intervention	Outcomes measured	Main findings and analytical comparison
[18]	Randomized controlled trial	110 AIS	Active self-correction exercises vs usual care	Cobb angle, QoL	Significant improvement in spinal deformity and HRQoL. Supports corrective exercise efficacy, although psychosocial domains were less analytically explored compared with the present study.
[13]	Assessor-blinded RCT	50 AIS	Schroth PSSE + standard care vs standard care	Cobb angle, SRS-22	Clinically meaningful improvement in Cobb angle and HRQoL outcomes. Provides an important methodological benchmark; however, the present study extends the analysis through active GE comparison and broader psychosocial interpretation.
[12]	Randomized controlled trial	50 AIS	Schroth PSSE program	QoL, muscle endurance	Improved quality of life and trunk muscle endurance. Compared with the present study, the psychosocial effect appeared smaller, possibly related to the shorter 6-month intervention period.
[17]	Randomized controlled trial	45 AIS	3D Schroth exercises	Cobb angle, ATR, QoL	Significant improvement in trunk asymmetry and clinical outcomes. Similar structural improvements were observed, while the present study additionally emphasizes pain and psychosocial HRQoL domains.
[25]	Systematic review & meta-analysis	Multiple studies	Scoliosis-specific exercises	Cobb angle, QoL	Evidence supports beneficial effects of exercise therapy. The present study contributes a structured protocol, active comparator, and multidimensional HRQoL interpretation.

[7]	Systematic review & meta-analysis	Multiple studies	Schroth + stabilization exercises	Pain, Cobb angle	Positive effects on scoliosis-related outcomes. Relevant for pain and structural outcomes, although psychosocial domains remained less emphasized.
[19]	Network meta-analysis	Multiple studies	PSSE interventions	Cobb angle, HRQoL	PSSE ranked among the most effective exercise approaches. Supports PSSE effectiveness at the evidence-synthesis level, while the present study adds direct patient-level clinical data.
[21]	Systematic review & meta-analysis	Multiple studies	Schroth 3D exercises	Cobb angle	Significant improvement in spinal curvature. Strong structural evidence, although less focused on psychosocial HRQoL outcomes.
[14]	Randomized clinical trial	AIS patients	Long-term supervised Schroth	QoL, curve severity	Long-term supervised Schroth intervention improved clinical outcomes. Most comparable to the present study regarding duration and supervision.
[15]	Assessor-blinded RCT	AIS patients	Schroth vs Lyon method	Cobb angle, ATR, QoL	Schroth intervention demonstrated superior structural outcomes. The present study further highlights psychosocial HRQoL effects under comparison with General Exercises.
[16]	Comparative clinical study	AIS patients	Supervised vs home Schroth	SRS-22 outcomes	Both supervised and home-based interventions improved HRQoL. Highlights the importance of supervision and adherence in scoliosis rehabilitation.
[22]	Systematic review & meta-analysis	Multiple studies	PSSE interventions	Cobb angle, HRQoL	Beneficial effects of PSSE were confirmed, although heterogeneity across studies remained substantial.
[20]	Bayesian network meta-analysis	Multiple studies	Exercise therapies in AIS	Cobb angle, QoL	PSSE ranked among the most effective exercise-based approaches. The present study adds patient-level RCT evidence and domain-specific HRQoL interpretation.

[23]	Systematic review	Multiple studies	Conservative scoliosis treatment	Curve progression	Exercise therapy may be beneficial in mild AIS. Foundational evidence, although less aligned with contemporary PSSE-Schroth approaches.
[24]	Updated systematic review	Multiple studies	Physical exercise interventions	Cobb angle, function	Exercise may contribute to curve stabilization. Methodological variability across studies limited direct comparison of psychosocial outcomes.

Previous studies generally support the effectiveness of scoliosis-specific rehabilitation in adolescents with idiopathic scoliosis, although they differ in treatment duration, supervision, comparator type, and clinical focus. Most earlier studies mainly evaluated structural outcomes such as Cobb angle and trunk asymmetry, while psychosocial aspects of health-related quality of life, particularly self-image and mental health, were less frequently explored in detail. In comparison with previous randomized trials, the present study used General Exercises as an active comparator, reflecting a more realistic conservative rehabilitation setting. The study also included effect-size reporting, MCID analysis, subgroup analysis, and sensitivity analysis, allowing a broader interpretation of treatment effects beyond statistical significance alone, see Table 2. Additionally, the findings suggest that both interventions improved pain and health-related quality of life, while the additional benefits of PSSE-Schroth appeared to be more evident in psychosocial domains, especially self-image and mental health.

The comparative benchmarking presented in this table shows that previous randomized studies generally support the effectiveness of scoliosis-specific rehabilitation in adolescents with idiopathic scoliosis, particularly for improving health-related quality of life. Furthermore, important differences remain across studies regarding intervention duration, supervision intensity, comparator type, and outcome emphasis. Earlier trials frequently focused on structural correction and overall HRQoL, whereas the present study additionally explored domain-specific psychosocial responses using effect-size interpretation and MCID analysis. Compared with several shorter-duration studies, the present trial demonstrated larger improvements in self-image and mental health domains. Figure 1 depict the conceptual clinical pathway.

These differences may be associated with the prolonged 12-month supervised intervention, repeated corrective practice, and structured adherence monitoring. At the same time, the findings should be interpreted within the broader context of multidimensional rehabilitation, where biomechanical correction, postural adaptation, and psychosocial factors may interact to influence patient-reported outcomes. Based on the current evidence and the multidimensional findings reported across previous PSSE studies, a conceptual clinical pathway was proposed to illustrate how prolonged supervised PSSE-Schroth rehabilitation may influence pain and HRQoL outcomes in adolescents with idiopathic scoliosis.

Table 2. Effect-size comparison and analytical benchmarking of pain and HRQoL outcomes across randomized PSSE studies in adolescents with idiopathic scoliosis

Study	Study design	Main pain/HRQoL outcome	Reported effect magnitude	Intervention duration	Analytical interpretation relative to the present study
[18]	Randomized controlled trial	HRQoL	Moderate improvement in quality of life and postural correction	12 months	Supports corrective exercise efficacy, although psychosocial domains were less analytically explored compared with the present study.
[13]	Assessor-blinded RCT	SRS-22 outcomes, HRQoL	Clinically meaningful improvement in HRQoL and Cobb angle	6 months	Provides an important methodological benchmark; however, the present study extends the analysis through active GE comparison and broader psychosocial interpretation.
[12]	Randomized controlled trial	HRQoL, self-image	Moderate psychosocial improvement (~d ≈ 0.5–0.6)	6 months	Compared with the present study (self-image d = 1.05), the smaller psychosocial effect may reflect shorter intervention duration and lower cumulative supervised exposure.
[17]	Randomized controlled trial	QoL, pain-related clinical improvement	Clinically meaningful improvement in QoL and trunk asymmetry	6 months	Similar improvements in clinical outcomes were observed, although the present study demonstrated broader HRQoL benchmarking and larger psychosocial effect sizes.
[14]	Randomized clinical trial	QoL	Sustained improvement during supervised intervention	Long-term supervised program	Most comparable regarding duration and supervision; however, the present study additionally incorporated MCID interpretation and domain-specific HRQoL analysis.

[15]	Assessor-blinded RCT	QoL, ATR, clinical outcomes	Large structural and clinical improvement favoring the Schroth intervention	8–12 months	Confirms superiority of scoliosis-specific rehabilitation for structural outcomes, while the present study additionally highlights the magnitude of the psychosocial effect.
Present study	Randomized controlled trial	Pain, self-image, mental health, HRQoL	Large psychosocial effect sizes (self-image d = 1.05; mental health d = 1.21; pain d = 1.06)	12 months	The larger psychosocial response may reflect prolonged supervised intervention, repeated corrective exposure, adherence monitoring, and cumulative postural retraining effects.

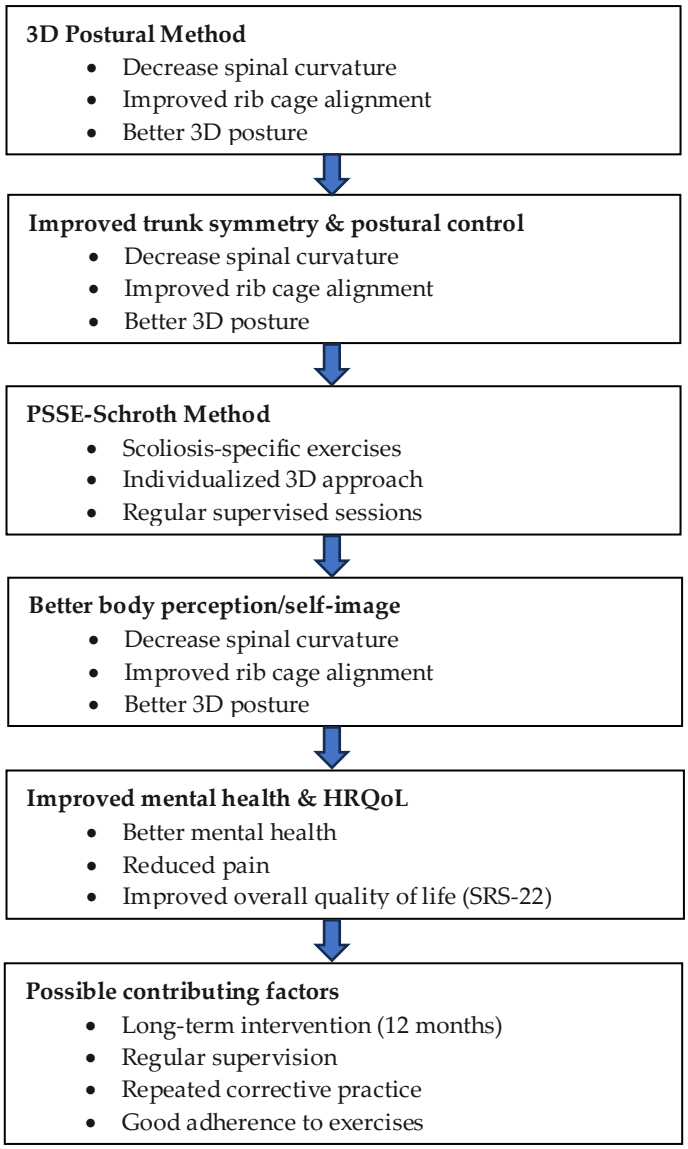

Figure 1. Conceptual clinical pathway

PSSE-Schroth aims to achieve three-dimensional correction of spinal deformity, potentially improving trunk symmetry and postural control. These physical improvements may enhance body perception and self-image, contributing to better mental health, reduced pain, and improved health-related quality of life.

METHODOLOGY

This prospective, randomized controlled trial was conducted for a twelve-month period, between May 2024 to November 2025. A total of 102 adolescents were initially assessed for eligibility, of whom 80 participants met the inclusion criteria and were enrolled in the study. All participants were aged 10 to 18 years and had a confirmed diagnosis of Idiopathic Scoliosis (IS) established by a specialist physician. The inclusion criteria were: diagnosed with Idiopathic Scoliosis, age between 10 and 18 years, Risser sign 0–3, and a Cobb angle ranging from 10° to 25°. Exclusion criteria included congenital or neuromuscular scoliosis, the presence of leg length discrepancy, and a history of previous spinal surgery. Eligible participants were randomly allocated to two intervention groups. Forty adolescents were assigned to the Physiotherapeutic Scoliosis-Specific Exercise (PSSE) group, while the remaining forty followed a General Exercise (GE) program. Randomization was performed using a block randomization method in order to ensure equal allocation of participants between groups. The random allocation sequence was generated prior to enrollment and participants were assigned to groups according to the predetermined block sequence. Supervised rehabilitation sessions were conducted twice weekly for the first six months and once weekly during the second six months, each session lasting 45 minutes, and were led by specialized physiotherapists at Toscana Clinic and the University Hospital of Trauma in Albania.

In addition, all participants performed a home-based exercise program five times per week, following individualized instructions tailored to their assigned intervention. A priori sample size estimation was performed using G*Power software for a two-tailed independent samples comparison. Assuming a moderate-to-large expected effect size (Cohen's $d \approx 0.65$), an alpha level of 0.05, and a statistical power of 0.80, the required sample size was approximately 76 participants. Therefore, the final sample of 80 participants (40 per group) was considered adequate for the planned analyses. Outcome assessment and statistical analysis were performed by investigators who were blinded to group allocation. Due to the nature of the intervention programs, physiotherapists delivering the treatments could not be blinded. Adherence to the home exercise program was monitored using exercise diaries completed by parents or legal guardians. These diaries were periodically collected and reviewed by the supervising physiotherapists to monitor compliance with the prescribed exercise protocol. The study protocol was approved by the Ethics Committee of the University of Medicine (protocol number 825/2). Written informed consent was obtained from the parents or legal guardians of all participants prior to study enrollment. The primary outcome of the study was pain, assessed using the pain domain of the Scoliosis Research Society-22 (SRS-22) questionnaire as a measure of Health-Related

Quality of Life (HRQoL). Secondary HRQoL domains (self-image, function, mental health, and satisfaction) were also evaluated. Outcome data were collected at baseline and after twelve months of rehabilitation. Statistical analyses were performed using SPSS software (version 25.0). Descriptive statistics were calculated for all variables. Between-group comparisons were performed using independent samples t-tests, while within-group changes between baseline and follow-up were analyzed using paired t-tests. When necessary, non-parametric alternatives (Mann–Whitney U test and Wilcoxon signed-rank test) were applied. Statistical significance was set at $p < 0.05$ for all analyses. Compliance with the prescribed home exercise program was monitored through exercise diaries completed by the participants' parents or legal guardians and periodically reviewed by the supervising physiotherapists. Adherence was categorized into three levels: excellent compliance (A), defined as performing the exercises more than five times per week; moderate compliance (B), defined as performing the exercises three to four times per week; and low compliance (C), defined as performing the exercises fewer than two times per week.

INTERVENTIONS

Physiotherapeutic Scoliosis-Specific Exercises (PSSE) constitute a conservative, three-dimensional therapeutic approach for the management of adolescent idiopathic scoliosis [9]. The PSSE-Schroth method is characterized by individualized exercise prescription based on curve pattern classification and emphasizes active patient participation through postural awareness and neuromuscular control [11]. Core components of PSSE include three-dimensional active autocorrection, spinal self-elongation, rotational angular breathing, and the integration of corrected postures into activities of daily living [9-13]. Growing evidence supports the effectiveness of scoliosis-specific exercise programs in adolescents with idiopathic scoliosis, demonstrating beneficial effects on pain reduction, aesthetic appearance, postural balance, and health-related quality of life. Moreover, PSSE has been shown to contribute to the stabilization or reduction of spinal curvature progression, particularly in patients with mild to moderate curves during growth [10, 15, 23-26]. In the present study, the PSSE intervention was implemented following principles described in the SOSORT guidelines for conservative scoliosis management [9]. Each rehabilitation session lasted approximately 45 minutes and was conducted under the supervision of physiotherapists trained in scoliosis-specific rehabilitation. The sessions were structured into several sequential components. Initially, patients performed spinal mobilization and preparatory activation exercises aimed at improving flexibility and neuromuscular readiness. This phase was followed by specific PSSE-Schroth exercises focusing on three-dimensional spinal correction, active postural autocorrection, rotational breathing techniques, and trunk stabilization. Particular emphasis was placed on correcting the individual curve pattern through guided postural adjustments and controlled breathing strategies. The final part of each session focused on stabilization exercises and the integration of corrected postures into functional positions and activities

of daily living [11]. Exercise selection and progression were individualized according to each participant's curve characteristics, physical capacity, and treatment response.

The protocol was standardized across therapists through internal clinical guidelines used at Toscana Clinic and the University Hospital of Trauma to ensure consistency in exercise delivery. In contrast, the General Exercises (GE) intervention represents a non-specific physical activity program aimed at improving overall physical fitness rather than directly addressing spinal deformity. GE programs typically focus on global components such as muscle strength, flexibility, endurance, coordination, and cardiovascular fitness, without individualized correction of scoliotic curves [9, 16, 24]. In the present study, the GE protocol was developed in accordance with international physical activity guidelines for children and adolescents [27]. Each GE session also lasted approximately 45 minutes and followed a standardized structure. The sessions began with a general warm-up phase consisting of light aerobic activity and joint mobilization exercises. This was followed by strengthening exercises targeting the trunk flexor and extensor muscles, general core stabilization exercises, and body-weight resistance exercises. The program also included stretching exercises for major muscle groups in order to improve flexibility and maintain balanced musculoskeletal function. The program included stretching exercises, general core stabilization, body-weight resistance training, and low-impact aerobic activities such as walking. Participants attended two supervised sessions per week and were encouraged to maintain an active lifestyle through unsupervised home-based activities. To enhance treatment adherence, participants in both groups were instructed to perform home-based exercises five times per week.

Compliance with the prescribed home program was monitored through exercise diaries completed by the parents or legal guardians of the participants. These diaries were periodically collected and reviewed by the supervising physiotherapists. Although general exercise programs may positively influence physical conditioning and overall posture, current literature suggests that they are less effective than scoliosis-specific exercise approaches in altering curve magnitude, improving trunk asymmetry, or enhancing self-image and disease-specific quality of life outcomes in adolescents with idiopathic scoliosis [6, 9, 12, 24].

RESULTS

A total of 102 adolescents were assessed for eligibility between May 2024 to November 2025. Of these, 80 met the inclusion criteria and were randomly assigned to either the PSSE-Schroth group (n = 40) or the control group performing general therapeutic exercises (n = 40), see Figure 2.

All participants completed baseline assessments, and 66 (82.5%) completed the full intervention period (eight participants in the PSSE-Schroth group and five in the control group discontinued due to personal reasons unrelated to the study protocol). One patient in the control group exceeded the clinical threshold for brace indication after 6 months.

Baseline demographic and clinical characteristics were statistically comparable between groups ($p > 0.05$) (Table 3). Mean age was 12.93 ± 2.13 years in the PSSE-Schroth group and 13.45± 2.41 years in the control group. No significant differences between groups were observed related to age, weight, height, Cobb angle, and riser sign ($p > 0.05$).

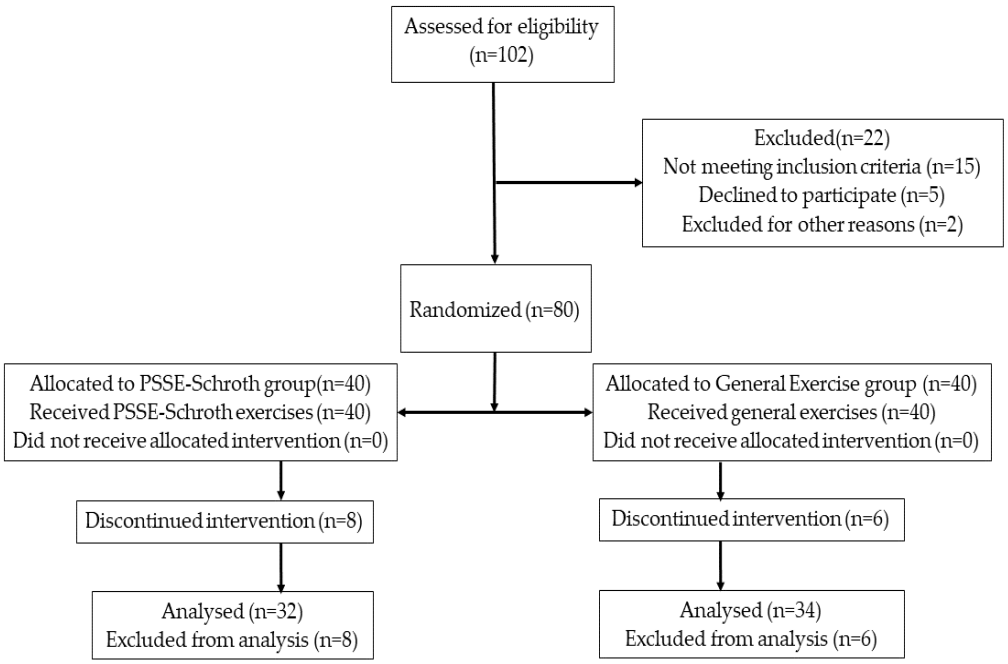

Figure 2. CONSORT Flow Diagram

After 12 months of treatment, both the PSSE-Schroth and General Exercise (GE) groups demonstrated statistically significant within-group improvements across all SRS-22 domains after the intervention period, $p < 0.001$ for all comparisons (Table 4)

Table 3. Baseline demographic and clinical characteristics of participants

	PSSE-Schroth Group N=40 (M±SD)	**GE Group N=40 (M±SD)**	**t- value**	**p- value**
Age (years)	12.93 ± 2.13	13.45 ± 2.41	-1.03	0.305
Gender (F/M)	26/14	24/16	$X^2 = 0.05$	0.818
Weight (kg)	46.93 ± 10.22	43.88 ± 7.86	1.50	0.139
Height(cm)	157.15 ± 13.24	154.50 ± 11.79	0.95	0.347
BMI (kg/m^2)	18.83 ± 2.49	18.30 ±1.96	1.04	0.302
Risser sign (0-3)	1.7 ± 0.8	1.6 ± 0.7		0.833
Thoracic Cobb angle (°)	15.70 ± 2.97	14.48 ± 3.06	1.48	0.145
Lumbar/Thoraco-lumbar Cobb angle (°)	16.64 ± 3.39	15.18 ±3.29	1.85	0.068

Values expressed as mean ± SD

Table 4. Comparison of pre- and post-treatment effects between PSSE-Schroth and control groups on SRS-22.

Outcome	Pre-treatment Mean (SD)	Post-treatment Mean (SD)	Within-group comparison Wilcoxon signed-rank test (p-value)	Effect size Cohen's d	Between groups Mann-Whitney U test (p-value)	Mean Difference between groups	CI 95%
SRS-22 Function							
PSSE-Schroth group	4.00 ±0.60	4.31 ±0.65	Z=-2.92 p=0,004	0.61	U= -1.35 p= 0.176	-0.33	{-0.54 to -0.12}
Control Group	3.81 ±0.49	4.13 ±0.58	Z=-3.47 p=0.001	0.65			
SRS-22 Pain							
PSSE-Schroth group	3.93 ±0.50	4.50 ±0.44	Z=-4.14 p<0,001	1.06	U=-1.79 p =0,074	-0.55	{-0.74 to-0.36}
Control Group	3.86 ±0.59	4.34 ±0.43	Z=-3.87 p<0,001	0.88			
SRS-22 Self-image							
PSSE-Schroth group	3.32 ±0.46	4.04 ±0.55	Z= -4.16 p<0,001	1.05	U= -1.96 p =0,050	-0.73	{-1.02 to -0.44}
Control Group	3.27±0.42	3.78 ±0.59	Z= -3.81 p<0,001	0.77			
SRS-22 Mental Health							
PSSE-Schroth group	3.70 ±0.59	4.29±0.50	Z= -4.46 p <0,001	1.21	U= -2.37 p =0,018	-0.60	{-0.92 to -0.28}
Control Group	3.60 ±0.49	3.99 ±0.61	Z= -3.57 p <0,001	0.60			
SRS-22 Total							
PSSE-Schroth group	3.78 ±0.44	4.26 ±0.45	Z=-4.07 p <0,001	0.95	U= -1.35 p =0,176	-0.48	{-0.78 to -0.18}
Control Group	3.65 ±0.61	4.09 ±0.53	Z= -4.13 p <0,001	0.81			

For the function domain, improvements were observed in both groups; however, the between-group comparison was not statistically significant (p = 0.176), with a mean difference of −0.33 (95% CI: −0.54 to −0.12), indicating comparable functional gains between interventions. In the pain domain, both groups showed significant reductions in pain scores, with a large effect size in the PSSE group (Cohen's d = 1.06). The between-group comparison favored the PSSE group, showing a mean difference of −0.55 (95% CI: −0.74 to −0.36), although this difference did not reach statistical significance (p = 0.074). For self-image, a statistically significant between-group difference was observed in favor of the PSSE-Schroth group (p = 0.050). The mean difference was −0.73 (95% CI: -1.02 to -0.44, indicating a greater improvement in perceived body image among patients undergoing PSSE. This domain also demonstrated a large within-group effect size in the PSSE group (d = 1.05). Similarly, in the Mental Health domain, the PSSE group showed significantly greater improvement compared with the GE group (p = 0.018), with a mean difference of −0.60 (95% CI: −0.92 to −0.28). The within-group effect size for the PSSE group was large (d = 1.21), suggesting a clinically meaningful benefit. Regarding the SRS-22 total score, both groups exhibited significant improvements from baseline (p < 0.001). Although the PSSE group demonstrated a larger effect size (d = 0.95) compared with the GE group (d = 0.81), the between-group difference was not statistically significant (p = 0.176), with a mean difference of −0.48 (95% CI: −0.51 to −0.66). Additionally, while both intervention approaches resulted in significant improvements in health-related quality of life, the PSSE-Schroth program showed superior outcomes in psychosocial domains, particularly self-image and mental health, as reflected by statistically significant between-group differences and larger effect sizes.

A mixed-design ANOVA was conducted to examine the effects of treatment group (PSSE-Schroth vs general exercises) and time (baseline vs 12 months) on SRS-22 total scores, see Table 5.

Table 5. Mixed-design ANOVA examining the effects of group and time on SRS-22 total score

Effect	df	F	p value
Group	1	2.35	0.129
Time	1	36.31	<0.001
Group × Time	1	0.01	0.922

F= statistic from analysis of variance; df = degrees of freedom; Group = treatment group (PSSE-Schroth vs general exercise); Time = measurement time (baseline and 12-month follow-up); Group × Time = interaction effect (changes over time)

The analysis revealed a significant main effect of time (F = 36.31, p < 0.001), indicating that both groups demonstrated significant improvements in health-related quality of life over the 12-month intervention period. The main effect of group was not statistically significant (F = 2.35, p = 0.129), suggesting comparable overall SRS-22 total scores between the PSSE-Schroth and control groups. Furthermore, the interaction between group and

time was not significant (F = 0.01, p = 0.922), indicating that the magnitude of improvement over time was similar in both groups.

An ANCOVA analysis was performed to compare post-treatment SRS-22 domain scores between groups while adjusting for baseline values, see Table 6.

Table 6. ANCOVA analysis comparing post-treatment SRS-22 domain scores between groups adjusted for baseline values

Domain	Mean Difference	95% CI	p value	Partial η^2
Function	-0.06	-0.31 to 0.18	0.620	0.004
Pain	-0.14	-0.33 to 0.05	0.156	0.032
Self-image	-0.25	-0.53 to 0.03	0.077	0.049
Mental Health	-0.26	-0.51 to -0.01	0.040	0.065
SRS-22 Total	-0.10	-0.33 to 0.13	0.388	0.012

ANCOVA = analysis of covariance; Adjusted mean difference = estimated difference between PSSE-Schroth and control groups after adjusting for baseline values; CI = confidence interval; p = probability value; η^2 = partial eta squared representing the effect size of the treatment effect.

After controlling for baseline differences, a statistically significant difference between groups was observed in the mental health domain (adjusted mean difference = −0.26, 95% CI −0.51 to −0.01, p = 0.040), indicating greater improvement in psychological well-being among participants treated with the PSSE-Schroth method. Differences in the self-image domain approached statistical significance (p = 0.077), suggesting a trend toward improved body perception in the PSSE group. However, no statistically significant adjusted differences were observed for function (p = 0.620), pain (p = 0.156), or the overall SRS-22 total score (p = 0.388). In the PSSE group, excellent compliance was observed in 37.5% of participants, moderate compliance in 53.1%, and low compliance in 9.4%. In the GE group, excellent compliance was reported in 35.3% of participants, moderate compliance in 41.2%, and low compliance in 23.5%. The majority of participants in both groups demonstrated moderate to high adherence to the prescribed home-based exercise program.

MCID analysis based on the thresholds proposed by Carreon et al. demonstrated that a higher proportion of patients in the PSSE-Schroth group achieved clinically meaningful improvement in the self-image domain compared with the general exercise group (46.9% vs 20.6%, p = 0.045), see Table 7.

For the remaining domains, including function, pain, mental health, and the total SRS-22 score, the proportion of patients achieving MCID did not significantly differ between groups.

Subgroup analysis based on age and skeletal maturity (Risser sign) did not demonstrate statistically significant differences between the PSSE-Schroth and general exercise groups. In patients aged 10–13 years, the mean improvement in SRS-22 total score was 0.41 in the PSSE group compared with 0.32 in the control group (p = 0.291), see Table 8.

Table 7. MCID achievement for SRS-22 domains

Domain	PSSE ≥ MCID n (%)	GE ≥ MCID n (%)	p value (χ^2)
Function	24 (75.0%)	25 (73.5%)	1.000
Pain	23 (71.9%)	26 (76.5%)	0.885
Self-image	15 (46.9%)	7 (20.6%)	0.045
Mental Health	28 (87.5%)	24 (70.6%)	0.168
SRS-22 Total	19 (59.4%)	18 (52.9%)	0.781

Table 8. Subgroup analysis according to age and Risser sign

Subgroup	PSSE Mean Change	GE Mean Change	p value
Age 10–13	0.41	0.32	0.291
Age 14–18	0.53	0.52	0.790
Risser 0–1	0.44	0.46	0.948
Risser 2–3	0.49	0.42	0.565

Among adolescents aged 14–18 years, both groups demonstrated similar improvements (0.53 vs 0.52, p = 0.790). Similarly, no significant differences were observed according to the Risser stage. For patients with Risser 0–1, the mean change in SRS-22 total score was 0.44 in the PSSE group and 0.46 in the control group (p = 0.948). In the Risser 2–3 subgroup, improvements were 0.49 and 0.42, respectively (p = 0.565). These findings suggest that the treatment effect on SRS-22 total score was consistent across different age groups and levels of skeletal maturity, see Table 9.

Table 9. Sensitivity analysis including dropouts

Analysis	PSSE Mean Change	GE Mean Change	p value
Per-protocol (n = 32 vs 34)	0.46	0.44	0.635
Sensitivity (n = 40 vs 40)*	0.37	0.38	0.885

**Drop-outs assumed to have no improvement (change = 0).*

A sensitivity analysis was performed to evaluate the robustness of the primary outcome results considering participant dropouts. In the primary per-protocol analysis, including only participants who completed the intervention (n = 66), the mean improvement in SRS-22 total score was 0.46 in the PSSE group and 0.44 in the general exercise group (p = 0.635). To assess the potential impact of missing data, a conservative sensitivity analysis was conducted assuming that participants who discontinued the intervention experienced no improvement in SRS-22 scores. Under this assumption, the mean change was 0.37 in the PSSE group and 0.38 in the control group (p = 0.885). The results remained consistent with

the primary analysis, indicating that the study findings were robust to potential bias introduced by dropouts.

To provide a conceptual interpretation of the rehabilitation effects, a system-based representation is illustrated in Figure 3.

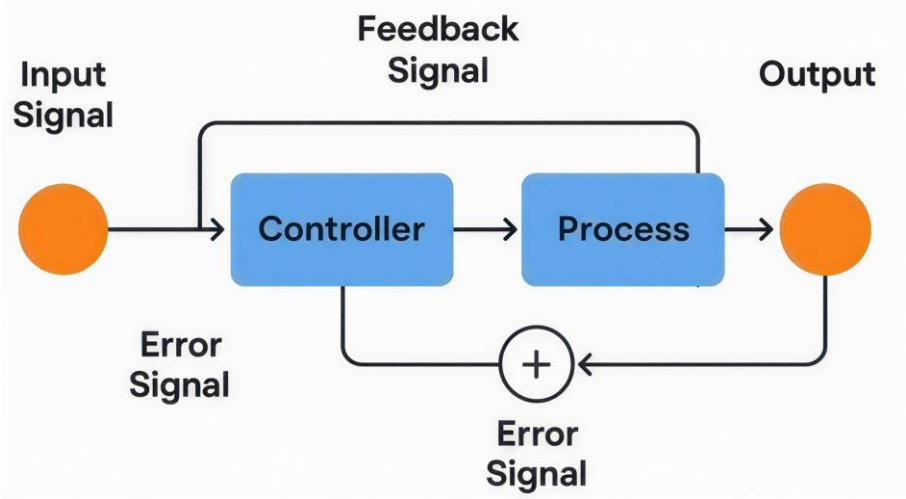

Figure 3. Conceptual control system model applied to scoliosis rehabilitation. The exercise intervention acts as the input signal, while the neuromuscular system functions as a controller regulating postural alignment. Biomechanical adaptation represents the process, producing clinical outputs such as pain reduction and improved health-related quality of life. Sensory feedback enables continuous error correction, forming a closed-loop system that may be enhanced by physiotherapeutic scoliosis-specific exercises.

In this framework, the exercise interventions (PSSE-Schroth and General Exercise) can be considered as system inputs that influence internal processes such as biomechanical correction and sensorimotor adaptation. These processes contribute to clinical outputs, including pain reduction and improvements in health-related quality of life. As shown, both interventions produce beneficial outcomes, however, the PSSE-Schroth approach may involve more structured feedback mechanisms through postural correction and proprioceptive awareness, potentially explaining the greater improvements observed in psychosocial domains.

DISCUSSION

The present randomized controlled study evaluated the impact of a structured Physiotherapeutic Scoliosis-Specific Exercise (PSSE–Schroth) program compared with general therapeutic exercise on health-related quality of life (HRQoL) in adolescents with idiopathic scoliosis using the SRS-22 questionnaire. Both interventions produced significant improvements across all SRS-22 domains over the 12-month intervention period. However, the PSSE-Schroth program demonstrated greater improvements in psychosocial outcomes, particularly in self-image and mental health, where both statistically significant between-group differences and large effect sizes were observed.

One of the most important findings of the present study was the magnitude of improvement observed in the psychosocial domains. While previous randomized trials have reported beneficial effects of PSSE interventions on HRQoL, the effect sizes observed in the present study particularly for self-image (d = 1.05) and mental health (d = 1.21)—appear comparatively larger than those reported in several earlier studies [12, 14, 15, 17]. This difference may reflect the prolonged 12-month supervised intervention, repeated corrective exposure, structured adherence monitoring, and the use of General Exercises as an active comparator rather than observation or standard care alone.

Importantly, the present findings suggest that the psychosocial effects of PSSE-Schroth may become more pronounced over longer rehabilitation periods, potentially indicating a cumulative adaptation process rather than a short-term therapeutic response alone. This interpretation is supported by the progressive nature of postural retraining, proprioceptive adaptation, and body-awareness integration that characterize scoliosis-specific rehabilitation.

The self-image domain demonstrated the clearest superiority of PSSE-Schroth compared with general exercise. In addition to statistical significance, MCID analysis revealed that a substantially greater proportion of participants in the PSSE group achieved clinically meaningful improvement in body image perception. Previous studies have demonstrated that scoliosis-specific exercise programs can positively influence trunk appearance and body perception [12-16, 20]. However, earlier studies often emphasized structural correction or overall HRQoL rather than specifically analyzing the magnitude of psychosocial adaptation.

From an analytical perspective, the present findings raise the possibility that self-image may represent one of the most sensitive domains to intervention specificity in AIS rehabilitation. Unlike pain or general physical function, self-image is directly linked to body perception, visible deformity awareness, social confidence, and emotional adaptation during adolescence. Consequently, interventions specifically targeting three-dimensional postural correction and body awareness may exert disproportionately larger effects in this domain compared with non-specific exercise approaches.

The superior psychosocial outcomes observed in the PSSE-Schroth group may be explained through a multidimensional interaction between biomechanical correction, sensorimotor retraining, and psychosocial adaptation. From a systems perspective, the rehabilitation process in adolescent idiopathic scoliosis may be conceptualized as a human biomechanical system in which exercise interventions function as inputs, neuromuscular adaptation and postural correction represent internal system processes, and clinical outcomes such as pain reduction and improvements in health-related quality of life constitute system outputs. Within this framework, general exercise may be interpreted as a non-specific or open-loop intervention, whereas PSSE-Schroth incorporates elements of feedback-driven control through continuous postural correction, proprioceptive input, and motor learning. This feedback-oriented mechanism may partially explain the superior outcomes observed in psychosocial domains, particularly self-image and mental health, by

enhancing patient awareness, active engagement, and perceived control over the deformity. However, this interpretation should be considered conceptual, as the present study did not include direct biomechanical modelling or quantitative system identification. Three-dimensional spinal correction and active postural autocorrection may improve trunk symmetry and postural control, potentially influencing body perception and emotional well-being [10, 11]. In this context, PSSE-Schroth may function not only as a physical rehabilitation method but also as a cognitive-motor retraining approach integrating proprioception, visual feedback, motor learning, and postural awareness [10, 23].

However, although the present findings support a possible interaction between biomechanical correction and psychosocial adaptation, the exact mechanisms underlying these improvements remain uncertain. It is still unclear whether enhanced self-image primarily results from visible postural changes, increased movement confidence, therapist-patient interaction, repeated supervised engagement, or broader psychosocial adaptation occurring during long-term rehabilitation. Therefore, the proposed conceptual clinical pathway should be interpreted as a clinically grounded explanatory model rather than a directly verified mechanistic framework.

From a psychosocial perspective, disturbances in body image represent one of the most significant burdens experienced by adolescents with scoliosis and are strongly associated with reduced self-esteem, social withdrawal, and emotional distress [3,4]. The active participation required during PSSE rehabilitation may partially explain the superior outcomes observed in the present study. According to Berdishevsky et al., scoliosis-specific exercise schools incorporate visual feedback, proprioceptive retraining, and postural awareness strategies that encourage patients to actively engage in deformity correction [10]. This process may contribute not only to physical adaptation but also to increased self-efficacy and greater perceived control over the condition.

In addition to self-image improvement, the PSSE group demonstrated significantly greater improvement in the mental health domain compared with the control group. Adolescence represents a critical developmental stage in which body appearance and social acceptance strongly influence emotional well-being. The strong improvement observed in mental health may therefore reflect more than simple symptom reduction alone; it may indicate improved psychosocial adaptation to the condition itself. Previous studies have suggested that scoliosis-specific rehabilitation may positively influence emotional well-being [12, 23], although mental health has often been treated as a secondary rather than a central explanatory outcome.

Interestingly, the superiority of PSSE-Schroth was not uniformly observed across all SRS-22 domains. While psychosocial outcomes demonstrated statistically significant advantages, pain and functional improvements were more comparable between groups. This partially contrasts with some previous studies reporting broader superiority of scoliosis-specific rehabilitation across multiple clinical domains [13, 15].

One possible explanation is that general exercise itself may provide substantial benefits in adolescents through improved physical conditioning, muscular endurance, flexibility, and movement confidence. Consequently, certain HRQoL domains—particularly pain and function—may be less sensitive to intervention specificity than perceptual and psychosocial domains such as self-image. This interpretation may also explain why both groups demonstrated significant reductions in pain despite the absence of statistically significant between-group differences.

Pain reduction was observed in both intervention groups, with large within-group effect sizes. Although the between-group difference did not reach statistical significance, the magnitude of improvement was greater in the PSSE group. Several factors may explain this finding. First, adolescents with idiopathic scoliosis generally present with relatively low baseline pain levels compared with adult scoliosis populations, limiting the potential for large between-group differences. Second, general exercise programs themselves may positively influence pain through increased physical activity, improved muscular support, and enhanced movement tolerance. Therefore, pain outcomes in AIS may reflect a broader response to rehabilitation exposure rather than exclusively to scoliosis-specific correction.

Functional improvement was similarly observed in both groups, suggesting that general exercise programs may effectively improve daily physical capacity in adolescents. Nevertheless, the slightly larger functional effect size observed in the PSSE group may reflect improved neuromuscular control and postural stabilization associated with curve-specific retraining. Monticone et al. demonstrated that task-oriented corrective exercises may improve motor control and postural integration during daily activities [18]. However, the absence of significant between-group differences suggests that functional outcomes may be influenced by multiple overlapping rehabilitation factors rather than exclusively by intervention specificity.

When examining the overall SRS-22 total score, both groups demonstrated significant improvements over the 12-month intervention period. Although the PSSE group demonstrated larger overall effect sizes, the between-group differences did not reach statistical significance. This pattern is important because it highlights the multidimensional nature of HRQoL in AIS. Global HRQoL scores may dilute domain-specific psychosocial improvements by aggregating physical, emotional, and functional dimensions into a single composite outcome. Consequently, clinically meaningful psychosocial changes may not always translate into large differences in total HRQoL scores.

The analytical comparison with previous studies further suggests that intervention duration and supervision intensity may substantially influence psychosocial outcomes. Several earlier randomized trials used shorter intervention periods of approximately six months [12, 17], whereas the present study implemented a structured twelve-month supervised rehabilitation program. This raises the possibility that psychosocial adaptation in AIS rehabilitation may require prolonged exposure and repeated reinforcement before clinically meaningful changes become fully evident.

Another important distinction relates to comparator selection. Many previous studies compared PSSE interventions with observation, usual care, or standard management [12, 13]. In contrast, the present study used General Exercises as an active comparator, representing a more clinically realistic rehabilitation setting. This methodological difference may partly explain why the observed superiority of PSSE-Schroth was concentrated primarily within psychosocial domains rather than uniformly across all outcomes.

The present findings also contribute to an evolving biopsychosocial interpretation of scoliosis rehabilitation. Earlier scoliosis literature predominantly emphasized radiological outcomes such as Cobb angle, trunk rotation, and curve progression [7, 19–22]. However, the current findings suggest that the added value of PSSE-Schroth may extend beyond structural correction alone. Rather than functioning exclusively as a biomechanical intervention, PSSE-Schroth may influence how adolescents perceive, interpret, and psychologically adapt to their deformity over time.

At the same time, the present results should not be interpreted as evidence that PSSE-Schroth is universally superior across all clinical dimensions. The absence of significant differences in several HRQoL outcomes suggests that the benefits of PSSE may be domain-specific rather than global. This distinction is clinically important because treatment selection in AIS may need to consider the dominant burden experienced by each adolescent whether structural, functional, or psychosocial rather than relying exclusively on curve magnitude alone.

Importantly, the MCID analysis provided additional insight into the clinical relevance of the observed changes. While statistical significance evaluates the probability that differences are not due to chance, MCID analysis reflects whether improvements are meaningful from the patient's perspective. In the present study, a greater proportion of participants in the PSSE group achieved clinically meaningful improvement in self-image, reinforcing the clinical relevance of the psychosocial findings [5].

The present results should also be interpreted within the broader framework of SOSORT recommendations, which emphasize individualized scoliosis-specific rehabilitation during growth [9]. The superior psychosocial outcomes observed in the PSSE group support the theoretical rationale underlying these recommendations, particularly the importance of active self-correction, postural awareness, and individualized rehabilitation strategies.

Subgroup analyses according to age and skeletal maturity did not demonstrate statistically significant differences between interventions, suggesting that the psychosocial benefits of PSSE may remain relatively consistent across different stages of adolescent growth. In addition, sensitivity analyses incorporating participant dropouts demonstrated stable findings under conservative assumptions, supporting the robustness of the overall results.

Despite these strengths, several limitations should be acknowledged. The sample size, although comparable with previous randomized scoliosis trials, remains moderate and

may limit the detection of smaller between-group differences. In addition, the study was limited to a 12-month follow-up period, preventing evaluation of long-term sustainability of psychosocial adaptation and curve progression outcomes.

Another important limitation relates to mechanistic interpretation. Although the present findings support a relationship between PSSE-Schroth and psychosocial improvement, the study design does not allow direct determination of causality between postural correction, body perception, and mental health adaptation. Future studies incorporating objective postural analysis, body perception assessment, and psychological profiling may help clarify the pathways underlying these multidimensional treatment effects.

Furthermore, adherence to home-based rehabilitation was monitored through exercise diaries rather than objective digital monitoring systems. Variability in adherence may therefore have influenced the magnitude of treatment response. Finally, the study was conducted within a single regional rehabilitation context, which may limit generalizability to other healthcare systems and sociocultural populations.

Taken together, the present findings support a broader biopsychosocial interpretation of scoliosis rehabilitation in adolescents. Rather than functioning solely as a corrective biomechanical intervention, PSSE-Schroth may influence how adolescents perceive, interpret, and psychologically adapt to their deformity over time. Nevertheless, the variability observed across outcome domains also highlights the complexity of HRQoL responses in AIS and underscores the need for future studies investigating the mechanisms, durability, and patient-specific determinants of psychosocial improvement.

CONCLUSION

Significant improvements in pain and all domains of health-related quality of life were observed following both interventions in adolescents with idiopathic scoliosis over the 12-month period. The Schroth-based physiotherapeutic scoliosis-specific exercise (PSSE) program demonstrated larger effect sizes and significantly greater improvements in psychosocial domains, particularly self-image and mental health, compared to general exercise ($p = 0.018$). While both groups showed meaningful reductions in pain and improvements in functional outcomes, consistently greater clinical gains were observed in the PSSE group. These findings suggest that scoliosis-specific exercises provide added value beyond general physical activity by addressing the three-dimensional nature of the deformity as well as its psychosocial impact. Accordingly, the integration of PSSE-based rehabilitation into conservative management strategies for adolescents with idiopathic scoliosis is supported, in line with current SOSORT recommendations.

Future research should explore the application of system-based approaches to better understand rehabilitation mechanisms in adolescent idiopathic scoliosis. The use of biomechanical modeling, objective measurement tools, and feedback-driven rehabilitation strategies may enhance the evaluation of postural control and treatment response. Such

approaches could support the development of individualized, closed-loop rehabilitation protocols aimed at optimizing clinical outcomes and improving long-term management.

AUTHOR CONTRIBUTIONS

Conceptualization, E.S. and L.S.; Methodology, L.S.; Validation, V.N.; Investigation, F.K.; Resources, L.S.; Data Curation, V.N.; Writing –Original Draft Preparation, L.S.; Writing –Review & Editing, E.S.; Supervision, F.K; Project Administration, E.S.

CONFLICT OF INTERESTS

The authors declare no conflict of interest associated with this publication.

REFERENCES

1. Weinstein, S.L., Dolan, L.A., Cheng, J.C., Danielsson, A., Morcuende, J. A. Adolescent Idiopathic Scoliosis. *Lancet* **2008**, *371* (9623), 1527–1537.
2. Konieczny, M.R., Senyurt, H., Krauspe, R. Epidemiology of Adolescent Idiopathic Scoliosis. *J. Child Orthop.* **2013**, *7*(1), 3–9.
3. Ramirez, N., Johnston, C. E., Browne, R. H. The Prevalence of Back Pain in Children Who Have Idiopathic Scoliosis. *J. Bone Joint Surg. Am.* **1997**, *79*(3), 364–368.
4. Asher, M., Lai, S. M., Burton, D., Manna, B. The Reliability and Concurrent Validity of the Scoliosis Research Society-22 Patient Questionnaire for Idiopathic Scoliosis. *Spine* **2003**, *28*(1), 63–69.
5. Carreon, L.Y., Sanders, J.O., Diab, M., Sucato, D.J., Sturm, P.F., Glassman, S.D. The Minimum Clinically Important Difference in SRS-22 Domains after Surgical Correction of Adolescent Idiopathic Scoliosis. *Spine* **2010**, *35*(23), 2079–2083.
6. Bagó, J., Pérez-Grueso, F. J., Les, E., Hernández, P., Pellisé, F. Minimal Important Differences of the SRS-22 Questionnaire Following Surgical Treatment of Idiopathic Scoliosis. *Eur. Spine J.* **2009**, *18*(12), 1898–1904.
7. Dimitrijević, V., Viduka, D., Šćepanović, T., Maksimović, N., Giustino, V., Bianco, A., Drid, P. Effects of Schroth Method and Core Stabilization Exercises on Idiopathic Scoliosis: A Systematic Review and Meta-Analysis. *Eur. Spine J.* **2022**, *31*(12), 3500–3511.
8. Romano, M., Minozzi, S., Bettany-Saltikov, J., Zaina, F., Chockalingam, N., Kotwicki, T., Maier-Hennes, A., Negrini, S. Exercises for Adolescent Idiopathic Scoliosis. *Cochrane Database Syst. Rev.* **2012**, *2012*(8), CD007837.
9. Negrini, S., Donzelli, S., Aulisa, A.G., Czaprowski, D., Schreiber, S., de Mauroy, J. C., Diers, H., Grivas, T. B., Knott, P., Kotwicki, T., et al. 2016 SOSORT guidelines: orthopaedic and rehabilitation treatment of idiopathic scoliosis during growth. *Scoliosis Spinal Disord.* **2018**, *13*, 3.
10. Berdishevsky, H., Lebel, V. A., Bettany-Saltikov, J., Rigo, M., Lebel, A., Hennes, A., Romano, M., Białek, M., M'hango, A., Betts, T., et al. Physiotherapy scoliosis-specific exercises – a comprehensive review of seven major schools. *Scoliosis Spinal Disord.* **2016**, *11*, 20.
11. Karavidas, N., Iakovidis, P., Chatziprodromidou, I., Lytras, D., Kasimis, K., Kyrkousis, A., Apostolou, T. Physiotherapeutic Scoliosis-Specific Exercises (PSSE-Schroth) can reduce the risk for progression during early growth in curves below 25°: prospective control study. *Eur. J. Phys. Rehabil. Med.* **2024**, *60*(2), 331–339.
12. Schreiber, S., Parent, E.C., Hill, D.L., Hedden, D.M., Moreau, M.J., Southon, S.C. Schroth physiotherapeutic scoliosis-specific exercises for adolescent idiopathic scoliosis: how many

patients require treatment to prevent one deterioration? – results from a randomized controlled trial - "SOSORT 2017 Award Winner". *Scoliosis Spinal Disord.* **2017**, *12*, 26.

13. Schreiber, S., Parent, E.C., Khodayari Moez, E., Hedden, D.M., Hill, D.L., Moreau, M., Lou, E., Watkins, E.M., Southon, S.C. Schroth Physiotherapeutic Scoliosis-Specific Exercises Added to the Standard of Care Lead to Better Cobb Angle Outcomes in Adolescents with Idiopathic Scoliosis – an Assessor and Statistician Blinded Randomized Controlled Trial. *PLoS One* **2016**, *11*(12), e0168746.
14. Kyrkousis, A., Iakovidis, P., Chatziprodromidou, I.P., Lytras, D., Kasimis, K., Apostolou, T., Koutras, G. Effects of a Long-Term Supervised Schroth Exercise Program on the Severity of Scoliosis and Quality of Life in Individuals with Adolescent Idiopathic Scoliosis: A Randomized Clinical Trial Study. *Medicina* **2024**, *60*, 1637
15. Buyukturan, O., Kaya, M. H., Alkan, H., Buyukturan, B., Erbahceci, F. Comparison of the efficacy of Schroth and Lyon exercise treatment techniques in adolescent idiopathic scoliosis: A randomized controlled, assessor and statistician blinded study. *Musculoskelet. Sci. Pract.* **2024**, *72*, 102952.
16. Tombak, K., Yüksel, İ., Ozsoy, U., Yıldırım, Y., Karaşin, S. A Comparison of the Effects of Supervised versus Home Schroth Exercise Programs with Adolescent Idiopathic Scoliosis. *Children* **2024**, *11*, 354.
17. Kuru, T., Yeldan, İ., Dereli, E. E., Özdinçler, A. R., Dikici, F., Çolak, İ. The efficacy of three-dimensional Schroth exercises in adolescent idiopathic scoliosis: a randomised controlled clinical trial. *Clin. Rehabil.* **2016**, *30*(2), 181–190.
18. Monticone, M., Ambrosini, E., Cazzaniga, D., Rocca, B., Ferrante, S. Active self-correction and task-oriented exercises reduce spinal deformity and improve quality of life in subjects with mild adolescent idiopathic scoliosis. Results of a randomised controlled trial. *Eur. Spine J.* **2014**, *23*(6), 1204–1214.
19. Dong, H., You, M., Li, Y., Wang, B., Huang, H. Physiotherapeutic Scoliosis-Specific Exercise for the Treatment of Adolescent Idiopathic Scoliosis. A Systematic Review and Network Meta-analysis. *Am. J. Phys. Med. Rehabil.* **2024**, *104*(1), 14–25.
20. Jiang, Y., Peng, H., Song, Y., Huang, L., Chen, H., Li, P., Yang, G., Song, Y., Chen, Q., Yao, N. Evaluating exercise therapies in adolescent idiopathic scoliosis: a systematic review with Bayesian network meta-analysis. *PeerJ* **2025**, *13*, e19175.
21. Chen, C., Xu, J., Li, H. Effects of Schroth 3D Exercise on Adolescent Idiopathic Scoliosis: A Systematic Review and Meta-Analysis. *Children* **2024**, *11*(7), 806.
22. Jia, Q., Zhang, Y., Liu, H., Wang, L., Chen, X. Effectiveness of physical therapeutic scoliosis exercise (PSSE) intervention for adolescent idiopathic scoliosis: a systematic review and meta-analysis. *BMC Musculoskelet. Disord.* **2025**, *26*, 947.
23. Weiss, H.R., Goodall, D. The treatment of adolescent idiopathic scoliosis (AIS) according to present evidence. A systematic review. *Eur. J. Phys. Rehabil. Med.* **2008**, *44*(2), 177–193.
24. Fusco, C., Zaina, F., Atanasio, S., Romano, M., Negrini, A., Negrini, S. Physical exercises in the treatment of adolescent idiopathic scoliosis: An updated systematic review. *Physiother. Theory Pract.* **2011**, *27*(1), 80–114.
25. Thompson, J.Y., Williamson, E.M., Williams, M.A., Heine, P.J., Lamb, S.E. Effectiveness of scoliosis-specific exercises for adolescent idiopathic scoliosis compared with other non-surgical interventions: a systematic review and meta-analysis. *Physiotherapy* **2019**, *105*(2), 214–234.
26. Romano, M., Negrini, S. Manual therapy as a conservative treatment for adolescent idiopathic scoliosis: a systematic review. *Scoliosis* **2008**, *3*, 2.
27. Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., Carty, C., Chaput, J.P., Chastin, S., Chou, R., et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br. J. Sports Med.* **2020**, *54*(24), 1451–1462.