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Original Article

Synergistic Effects of Schroth Method with and Without Core Stabilization Exercises in Idiopathic Scoliosis

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ABSTRACT

Background: Idiopathic scoliosis is a three-dimensional spinal deformity that may affect spinal alignment, trunk endurance, chest mobility, body image, and health-related quality of life. The Schroth Method is a scoliosis-specific conservative intervention based on postural correction, spinal elongation, de-rotation, and rotational angular breathing, while core stabilization exercises aim to improve trunk control and spinal support. Objective: To compare the effects of the Schroth Method with and without core stabilization exercises on Cobb angle, lumbar extensor endurance, chest mobility, and quality of life in patients with idiopathic scoliosis. Methods: This assessor-blinded randomized controlled trial included 72 participants with idiopathic scoliosis, allocated equally into Group A and Group B. Group A received the Schroth Method combined with core stabilization exercises, while Group B received the Schroth Method alone. Treatment was provided for 10 weeks, with three supervised sessions per week. Outcomes were assessed at baseline, the 5th week, and the 10th week using Cobb angle, Sorensen test, chest mobility measurement, and SRS-22r domains. Data were analyzed using parametric repeated-measures approaches. Results: Both groups demonstrated significant improvement over time. Cobb angle decreased substantially in Group A and Group B. Group A showed greater improvement in Sorensen test scores, chest mobility, and SRS-22r function, pain, self-image, and mental health domains. At the 10th week, between-group differences favored Group A for Sorensen test and chest mobility. Conclusion: Adding core stabilization exercises to the Schroth Method may enhance functional endurance, chest mobility, and scoliosis-specific quality-of-life outcomes in idiopathic scoliosis rehabilitation. Verification of the inconsistent 10-week Cobb angle value is required before making a definitive claim regarding radiographic superiority. Keywords: Idiopathic scoliosis; Schroth Method; core stabilization exercises; Cobb angle; Sorensen test; chest mobility; SRS-22r; rehabilitation.

INTRODUCTION

Idiopathic scoliosis is a three-dimensional spinal deformity characterized by lateral curvature of the spine, vertebral rotation, and postural asymmetry, with diagnosis conventionally established when the Cobb angle exceeds 10 degrees on standing radiography. Although scoliosis may arise from congenital, neuromuscular, syndromic, traumatic, or other identifiable causes, idiopathic scoliosis is diagnosed when no specific underlying etiology is established. Adolescent idiopathic scoliosis is the most frequent clinical form and commonly emerges during the pubertal growth period, when rapid skeletal development may increase the risk of curve progression and associated functional compromise (1). The condition is clinically important because progressive spinal deformity can affect body alignment, trunk symmetry, respiratory mechanics, musculoskeletal endurance, pain, self-image, and health-related quality of life, particularly in young individuals undergoing physical and psychosocial development (2).

The Cobb angle remains the principal radiographic outcome used to quantify scoliosis severity and monitor curve progression or response to treatment. Mild curves are generally managed conservatively, whereas larger or progressive curves may require bracing or surgical consideration depending on age, skeletal maturity, curve magnitude, symptoms, and risk of progression. Conservative management is therefore a central component of scoliosis care, particularly for patients with mild to moderate idiopathic scoliosis, because early and appropriately targeted rehabilitation may reduce functional decline, improve postural control, and potentially limit progression during growth-sensitive periods (3). In addition to radiographic assessment, functional outcomes such as trunk muscle endurance, chest mobility, pain, self-image, and scoliosis-specific quality of life are increasingly recognized as necessary endpoints because patients may experience clinically meaningful improvement even when radiographic changes are modest (4).

Physiotherapeutic scoliosis-specific exercises have gained attention as individualized conservative interventions designed to address the three-dimensional nature of scoliosis. Among these, the Schroth Method is one of the most widely studied approaches and uses active postural correction, spinal elongation, sensorimotor training, mirror feedback, muscle symmetry training, and rotational angular breathing to improve trunk alignment and reduce asymmetric loading. Previous clinical trials and systematic reviews have reported that Schroth-based exercise programs can improve Cobb angle, trunk rotation, postural stability, and quality-of-life domains in patients with adolescent idiopathic scoliosis, although the magnitude of radiographic change may vary across studies and may not always exceed thresholds considered clinically meaningful (5,6). These findings suggest that the Schroth Method has therapeutic value, but also indicate that optimizing its effect may require integration with complementary strategies targeting trunk stability and muscular control.

Core stabilization exercises are designed to improve neuromuscular control and endurance of the deep trunk stabilizers, including the transversus abdominis, multifidus, pelvic floor, diaphragm, abdominal wall, spinal extensors, and pelvic stabilizers. These muscles contribute to spinal segmental control, postural endurance, load transfer, and respiratory–trunk coordination, all of which are relevant in idiopathic scoliosis because trunk muscle imbalance, asymmetrical activation patterns, reduced back-muscle endurance, and altered postural control may accompany spinal deformity (7). Prior evidence suggests that core stabilization can improve trunk symmetry, pain, functional capacity, and selected quality-of-life outcomes in scoliosis rehabilitation; however, its comparative effectiveness relative to scoliosis-specific exercise methods remains variable, and the optimal way to integrate core stabilization into scoliosis-specific protocols has not been fully established (8,9).

The available literature indicates that both Schroth exercises and core stabilization may benefit patients with idiopathic scoliosis, but important gaps remain. Several studies have compared Schroth exercises with other conservative approaches, and others have examined core stabilization either independently or alongside adjunctive interventions, yet fewer trials have directly evaluated whether adding a structured core stabilization protocol to the Schroth Method provides superior improvement in curve magnitude, lumbar extensor endurance, chest mobility, and scoliosis-specific quality of life over the same treatment period. This gap is clinically relevant because scoliosis is not only a radiographic deformity but also a functional disorder involving postural endurance, thoracic expansion, trunk control, self-image, and participation in daily activities (10,11). A combined intervention may offer additive benefit by using the Schroth Method to correct three-dimensional spinal alignment while using core stabilization to enhance the muscular support required to maintain corrected posture during function.

The present randomized controlled trial was therefore designed according to a PICO framework in which patients with idiopathic scoliosis aged 10 to 18 years represented the target population, the combined Schroth Method plus core stabilization exercises represented the experimental intervention, the Schroth Method alone represented the comparator, and Cobb angle, lumbar extensor endurance, chest mobility, and SRS-22r quality-of-life domains represented the primary clinical and functional outcomes. The study specifically aimed to determine whether adding core stabilization exercises to a structured Schroth exercise program would produce greater improvement over 10 weeks than Schroth exercises alone in individuals with idiopathic scoliosis. It was hypothesized that participants receiving the combined intervention would demonstrate greater reduction in Cobb angle and greater improvement in lumbar extensor endurance, chest mobility, and scoliosis-specific quality of life than participants receiving Schroth Method alone (12).

MATERIALS AND METHODS

This study was conducted as an assessor-blinded, parallel-group randomized controlled clinical trial to compare the effects of the Schroth Method combined with core stabilization exercises versus the Schroth Method alone in patients with idiopathic scoliosis. The trial was carried out at the University of Lahore Teaching Hospital over a nine-month period following institutional ethical approval. The study design was selected because random allocation allowed direct comparison of two conservative rehabilitation protocols while repeated outcome assessment permitted evaluation of change over time in radiographic, functional, respiratory, and quality-of-life outcomes.

Participants were recruited from patients presenting with clinically and radiographically diagnosed idiopathic scoliosis. Eligible participants were boys and girls aged 10 to 18 years with an X-ray-confirmed diagnosis of idiopathic scoliosis and a Cobb angle between 10° and 30°. Participants were included only when they fulfilled the operational definition of idiopathic scoliosis and were medically able to participate in supervised therapeutic exercise. Patients were excluded if they had scoliosis secondary to a known neurological, congenital, syndromic, traumatic, or other non-idiopathic cause; cerebral palsy, epilepsy, or another neurological disorder affecting motor control; major orthopedic conditions such as hip dysplasia, osteogenesis imperfecta, or clinically relevant leg-length discrepancy; previous spinal surgery including fusion or decompression; severe systemic disease including uncontrolled cardiovascular or autoimmune disorders; or any clinical condition that limited safe participation in the intervention protocol. Removing non-idiopathic and syndromic scoliosis from eligibility was necessary to preserve diagnostic homogeneity and ensure that treatment effects were interpreted specifically in relation to idiopathic scoliosis (13).

Eligible participants were selected through non-probability convenience recruitment and were then randomly allocated into two equal groups after baseline assessment. Random allocation was performed using a computer-generated sequence to reduce selection bias. Group A received the Schroth Method combined with core stabilization exercises, whereas Group B received the Schroth Method alone. Outcome assessment was performed by an assessor who was unaware of group allocation. Participants and treating therapists could not be blinded because of the nature of the exercise interventions; however, assessor blinding, standardized measurement procedures, equivalent treatment duration, and uniform assessment timing were used to reduce measurement and performance-related bias.

The sample size was calculated using Cobb angle as the principal outcome measure, with assumptions based on previously reported mean change values for exercise-based scoliosis interventions. Using a 95% confidence level and 80% power, the initial calculation indicated a minimum of 20 participants per group. Because clinical exercise trials with repeated follow-up require adequate group size for stable variance estimation and potential attrition, the target sample was increased to 30 participants per group and then inflated by 20% for anticipated dropout, resulting in a final recruitment target of 36 participants per group and a total sample size of 72 participants. This sample size was retained for the final analysis, with 36 participants allocated to each group.

Baseline demographic variables included age, sex, height, weight, and body mass index. The principal clinical outcome was curve magnitude measured by Cobb angle on radiography. Lumbar extensor endurance was assessed using the Sorensen test, chest mobility was measured using a non-stretch measuring tape at the xiphoid level during respiratory excursion, and scoliosis-specific quality of life was assessed using the Scoliosis Research Society-22 revised questionnaire. Cobb angle was measured in degrees, chest mobility was measured in centimeters, and quality-of-life domains were scored according to the SRS-22r scoring structure. The Sorensen test was used as a measure of lumbar extensor endurance, and its unit of reporting was standardized before analysis to ensure that the outcome scale remained consistent across baseline, mid-intervention, and post-intervention assessments (14,15).

All participants were assessed at three time points: baseline before intervention, the 5th week, and the 10th week after completion of the intervention period. Both groups completed supervised treatment for 10 weeks, with three sessions per week and each session lasting approximately 60 minutes. The Schroth component included warm-up mobility and stretching, mirror-assisted postural alignment, rotational angular breathing, pelvic correction, spinal elongation, shoulder counter-traction, side-lying expansion, de-rotation movements, wall-assisted correction, and breathing-integrated arm elevation. Exercises were individualized according to the direction of the scoliotic curve and were performed with therapist supervision to ensure corrective positioning, breathing control, and safe progression.

Participants in Group A received the same structured Schroth protocol plus progressive core stabilization exercises. During weeks 1 to 3, the core program emphasized abdominal drawing-in and bridge exercises with controlled activation. During weeks 4 to 7, progression included bird-dog, dead bug, and side-plank exercises to develop trunk endurance, lumbopelvic control, and anti-rotational stability. During weeks 8 to 10, advanced exercises included TheraBand rotations, bridge with marching, and resisted bird-dog variations. The progression was designed to reinforce corrected posture by improving activation and endurance of the deep trunk stabilizers while avoiding excessive spinal loading. Participants in Group B received the Schroth Method alone for the same treatment frequency and duration, ensuring that the primary difference between groups was the addition of core stabilization exercises in Group A.

Data were recorded on structured proformas and entered into SPSS version 27.0 for statistical analysis. Data integrity was maintained through standardized data collection procedures, verification of entered values against source records, consistent coding of categorical variables, and screening for missing or implausible values before analysis. Continuous variables were summarized as mean ± standard deviation when normally distributed, and categorical variables were summarized as frequency and percentage. Normality was evaluated using the Kolmogorov–Smirnov test because the total sample size exceeded 50 participants, supported by inspection of distributional patterns. Baseline comparability between groups was assessed using independent-samples tests for continuous variables and chi-square testing for categorical variables where appropriate.

The primary analysis evaluated differences in outcome trajectories between the two intervention groups across baseline, 5th week, and 10th week assessments. A mixed-design repeated-measures analysis was used to examine the effects of time, group, and the group × time interaction for Cobb angle, Sorensen test, chest mobility, and SRS-22r domain scores. Within-group changes over time were examined using repeated-measures analysis, while between-group comparisons at individual time points were interpreted cautiously and in relation to the overall interaction effect. Statistical significance was set at $p < 0.05$. Effect sizes were reported where available using partial eta squared for ANOVA-based comparisons, and confidence intervals were recommended for between-group change estimates to improve clinical interpretability. Missing data were handled by reviewing follow-up completeness before final analysis; participants with complete baseline, 5th-week, and 10th-week assessments were included in the repeated-measures analysis.

The study was conducted in accordance with institutional ethical standards. Ethical approval was obtained before participant recruitment, and written informed consent was obtained from all participants or their guardians where applicable. Participants were informed about the purpose of the study, voluntary participation, confidentiality of data, potential exercise-related discomfort, and their right to withdraw at any stage without penalty. Personal identifiers were removed from analytical files, and results were reported in aggregated form to preserve participant anonymity.

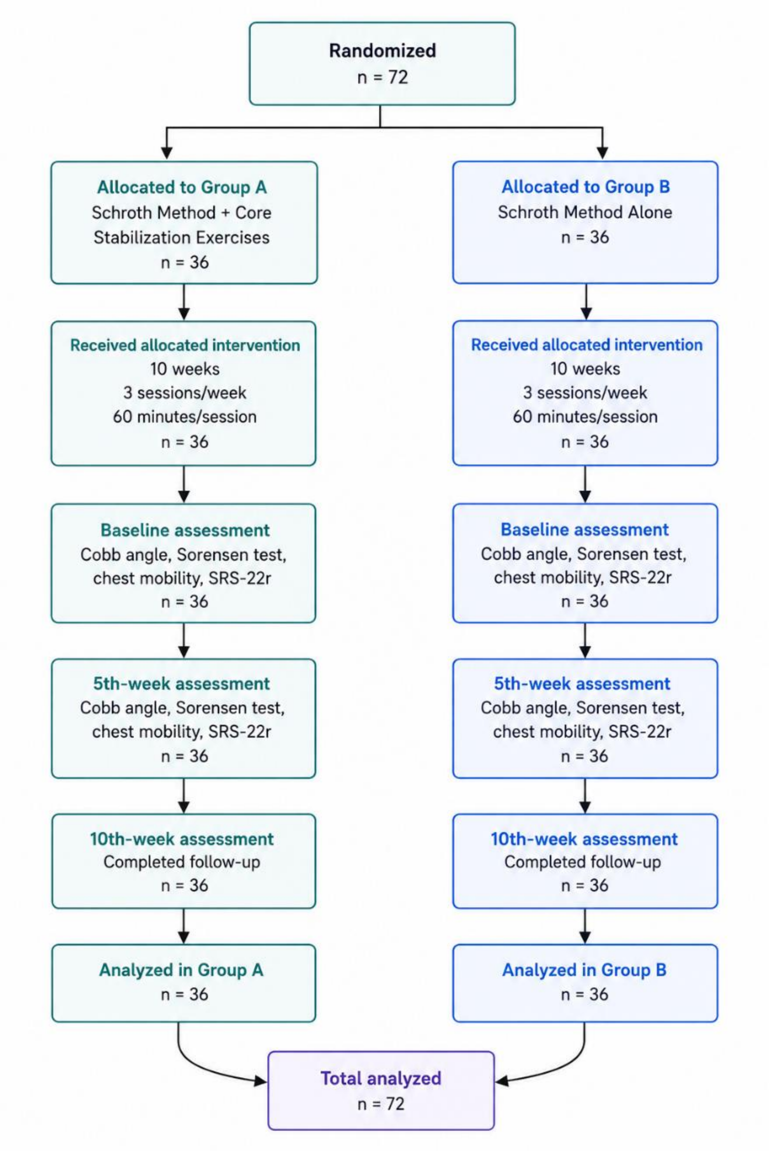


Figure 1 CONSORT Flowchart

RESULTS

A total of 72 participants with idiopathic scoliosis were included in the final analysis, with 36 participants allocated to Group A and 36 participants allocated to Group B. Group A received the Schroth Method combined with core stabilization exercises, whereas Group B received the Schroth Method alone. Baseline demographic characteristics were comparable between the two groups for age, weight, height, body mass index, and sex distribution. The two groups were similar at baseline across all measured demographic variables. The mean age was 14.222 ± 2.473 years in Group A and 14.555 ± 2.454 years in Group B. Baseline body weight, height, and BMI also showed no statistically significant between-group differences. Sex distribution was balanced, with females comprising 55.6% of Group A and 44.4% of Group B. Normality was assessed for baseline outcome variables using the Kolmogorov–Smirnov test because the total sample size exceeded 50 participants. All baseline outcome variables showed p-values greater than 0.05.

The Kolmogorov–Smirnov test indicated that baseline Cobb angle, Sorensen test, chest mobility, and SRS-22r subdomain scores were normally distributed. Parametric statistical analyses were therefore applied for the reported comparisons. Between-group comparisons of Cobb angle were conducted at baseline, 5th week, and 10th week. Baseline Cobb angle did not differ significantly between groups. A statistically significant between-group difference was reported at the 10th week.

Table 1. Baseline Demographic Characteristics of Participants

Variable	Group A Mean ± SD / n (%)	Group B Mean ± SD / n (%)	p-value
Age, years	14.222 ± 2.473	14.555 ± 2.454	0.568
Weight, kg	35.166 ± 2.903	35.405 ± 3.072	0.736
Height, ft	4.726 ± 0.430	4.814 ± 0.467	0.407
BMI, kg/m²	17.419 ± 3.823	16.891 ± 3.552	0.546
Female	20 (55.6)	16 (44.4)	0.346
Male	16 (44.4)	20 (55.6)	0.346

Table 2. Normality Assessment of Baseline Outcome Variables

Variable	Kolmogorov–Smirnov Statistic	df	p-value
Cobb angle at baseline	0.095	72	0.180
Sorensen test at baseline	0.100	72	0.071
Chest mobility at baseline	0.095	72	0.171
SRS-22r function at baseline	0.096	72	0.094
SRS-22r pain at baseline	0.100	72	0.073
SRS-22r self-image at baseline	0.096	72	0.094
SRS-22r mental health at baseline	0.095	72	0.182

df: degrees of freedom; SRS-22r: Scoliosis Research Society-22 revised questionnaire.

Table 3. Between-Group Comparison of Cobb Angle Across Assessment Points

Assessment Point	Group A Mean ± SD	Group B Mean ± SD	Mean Difference	p-value	Partial Eta Squared
Baseline	26.891 ± 4.879	25.327 ± 4.934	1.564	0.181	0.025
5th week	20.627 ± 5.350	22.811 ± 5.369	-2.184	0.088	0.041
10th week	12.000 ± 2.496	11.086 ± 3.742	0.914	0.019	0.076

Group A: Schroth Method plus core stabilization exercises; Group B: Schroth Method alone. Cobb angle is reported in degrees. Mean difference was calculated as Group A minus Group B.

At baseline, the mean Cobb angle was 26.891 ± 4.879° in Group A and 25.327 ± 4.934° in Group B. By the 5th week, the mean Cobb angle declined to 20.627 ± 5.350° in Group A and 22.811 ± 5.369° in Group B. At the 10th week, the mean Cobb angle was 12.000 ± 2.496° in Group A and 11.086 ± 3.742° in Group B, with a reported between-group p-value of 0.019 and partial eta squared of 0.076. Within-group repeated-measures analysis showed significant reductions in Cobb angle over time in both groups. Change scores were calculated from the reported baseline, 5th-week, and 10th-week mean values.

Table 4. Within-Group Change in Cobb Angle Across Assessment Points

Group	Baseline Mean ± SD	5th Week Mean ± SD	10th Week Mean ± SD	Change Baseline to 5th Week	Change Baseline to 10th Week	F	p-value
Group A	26.891 ± 4.879	20.627 ± 5.350	12.000 ± 2.496	-6.264	-14.891	248.270	<0.001
Group B	25.327 ± 4.934	22.811 ± 5.369	11.086 ± 3.742	-2.516	-14.241	107.611	<0.001

Cobb angle decreased significantly over time in both intervention groups. Group A showed a mean reduction of 6.264° by the 5th week and 14.891° by the 10th week, while Group B showed a mean reduction of 2.516° by the 5th week and 14.241° by the 10th week. The reported within-group repeated-measures analyses were statistically significant in both Group A and Group B. Between-group comparisons of lumbar extensor endurance, assessed using the Sorensen test, showed no statistically significant difference at baseline or the 5th week. A statistically significant between-group difference was reported at the 10th week. Group A: Schroth Method plus core stabilization exercises; Group B: Schroth Method alone. Mean difference was calculated as Group A minus Group B. Sorensen test unit/scoring should be reported consistently according to the final measurement scale used in analysis. At baseline, Sorensen test scores were 2.002 ± 0.836 in Group A and 2.201 ± 0.921 in Group B. By the 10th week, scores increased to 3.069 ± 1.029 in Group A and 2.557 ± 0.950 in Group B. The 10th-week between-group difference was 0.512, with a reported p-value of 0.032 and partial eta squared of 0.064. Within-group repeated-measures analysis showed significant improvement in Sorensen test scores over time in both groups.

Table 5. Between-Group Comparison of Sorensen Test Across Assessment Points

Assessment Point	Group A Mean ± SD	Group B Mean ± SD	Mean Difference	p-value	Partial Eta Squared
Baseline	2.002 ± 0.836	2.201 ± 0.921	-0.199	0.341	0.013
5th week	2.726 ± 0.818	2.415 ± 0.954	0.311	0.142	0.031
10th week	3.069 ± 1.029	2.557 ± 0.950	0.512	0.032	0.064

Table 6. Within-Group Change in Sorensen Test Across Assessment Points

Group	Baseline Mean ± SD	5th Week Mean ± SD	10th Week Mean ± SD	Change Baseline to 5th Week	Change Baseline to 10th Week	F	p-value
Group A	2.002 ± 0.836	2.726 ± 0.818	3.069 ± 1.029	0.724	1.067	30.159	<0.001
Group B	2.201 ± 0.921	2.415 ± 0.954	2.557 ± 0.950	0.214	0.356	39.195	<0.001

Sorensen test scores increased over time in both groups. Group A showed a mean increase of 1.067 from baseline to the 10th week, while Group B showed a mean increase of 0.356 over the same period. The repeated-measures analysis demonstrated statistically significant within-group changes in both groups. Between-group comparisons of chest mobility showed no statistically significant difference at baseline or the 5th week. A statistically significant between-group difference was reported at the 10th week.

Table 7. Between-Group Comparison of Chest Mobility Across Assessment Points

Assessment Point	Group A Mean ± SD	Group B Mean ± SD	Mean Difference	p-value	Partial Eta Squared
Baseline	3.361 ± 1.071	3.408 ± 0.882	-0.047	0.839	0.001
5th week	4.147 ± 0.937	3.808 ± 0.658	0.339	0.080	0.043
10th week	4.763 ± 0.880	4.244 ± 0.917	0.519	0.017	0.079

Chest mobility was similar between groups at baseline, with mean values of 3.361 ± 1.071 cm in Group A and 3.408 ± 0.882 cm in Group B. At the 10th week, chest mobility increased to 4.763 ± 0.880 cm in Group A and 4.244 ± 0.917 cm in Group B. The between-group difference at the 10th week was 0.519 cm, with a reported p-value of 0.017 and partial eta squared of 0.079. Within-group repeated-measures analysis showed significant improvement in chest mobility in both groups across the 10-week intervention period.

Table 8. Within-Group Change in Chest Mobility Across Assessment Points

Group	Baseline Mean ± SD	5th Week Mean ± SD	10th Week Mean ± SD	Change Baseline to 5th Week	Change Baseline to 10th Week	F	p-value
Group A	3.361 ± 1.071	4.147 ± 0.937	4.763 ± 0.880	0.786	1.402	31.165	<0.001
Group B	3.408 ± 0.882	3.808 ± 0.658	4.244 ± 0.917	0.400	0.836	8.328	<0.001

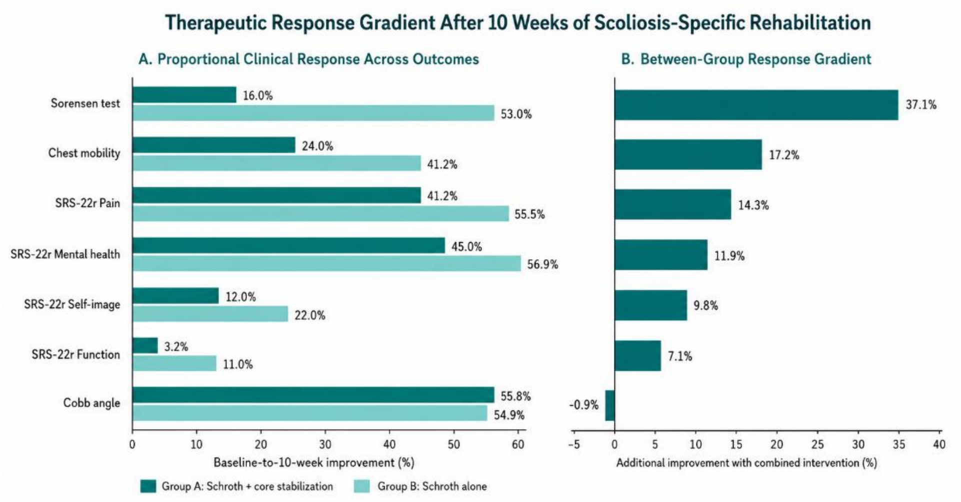
Table 9. Within-Group Comparison of SRS-22r Subdomain Scores Across Assessment Points

Domain	Group	Baseline Mean ± SD	5th Week Mean ± SD	10th Week Mean ± SD	Change Baseline to 10th Week	F	p-value
Function	Group A	2.987 ± 0.384	3.126 ± 0.427	3.297 ± 0.422	0.310	50.139	<0.001
Function	Group B	2.970 ± 0.313	2.975 ± 0.349	3.068 ± 0.437	0.098	0.992	0.381
Pain	Group A	2.122 ± 0.330	3.060 ± 0.456	3.308 ± 0.458	1.186	82.863	<0.001
Pain	Group B	2.162 ± 0.302	2.900 ± 0.456	3.061 ± 0.353	0.899	86.265	<0.001
Self-image	Group A	2.868 ± 0.420	3.198 ± 0.459	3.507 ± 0.472	0.639	48.247	<0.001
Self-image	Group B	2.909 ± 0.247	3.080 ± 0.317	3.271 ± 0.395	0.362	14.505	<0.001
Mental health	Group A	2.135 ± 0.324	2.738 ± 0.572	3.354 ± 0.432	1.219	144.043	<0.001
Mental health	Group B	2.162 ± 0.302	2.642 ± 0.467	3.139 ± 0.309	0.977	112.458	<0.001

Chest mobility increased significantly from baseline to the 10th week in both groups. Group A showed a mean increase of 1.402 cm, while Group B showed a mean increase of 0.836 cm. The magnitude of improvement was numerically greater in Group A. Scoliosis-specific quality of life was assessed using SRS-22r subdomain scores. Within-group repeated-measures analysis was reported for function, pain, self-image, and mental health across baseline, 5th-week, and 10th-week assessments.

SRS-22r subdomain scores improved over time in most domains. In Group A, statistically significant within-group improvements were observed in function, pain, self-image, and mental health. In Group B, statistically significant improvements were observed in pain, self-image, and mental health, while the function domain did not show a statistically significant within-group change. The largest baseline-to-10th-week improvements in Group A were observed for mental health and pain, whereas Group B showed its largest improvements in mental health and pain.

Overall, both intervention groups demonstrated improvement across radiographic, functional, respiratory, and quality-of-life outcomes over the 10-week intervention period. The combined intervention group showed greater mean improvement in Sorensen test scores, chest mobility, and most SRS-22r subdomains. Cobb angle decreased substantially in both groups; however, interpretation of between-group superiority for Cobb angle should be based on corrected change-score analysis or the final verified mixed repeated-measures model because the available manuscript values show a statistically significant 10th-week between-group difference but do not provide the paired-change variability required to calculate confidence intervals for change.



Therapeutic Response Gradient After 10 Weeks of Scoliosis-Specific Rehabilitation

The therapeutic response gradient demonstrated a broader pattern of improvement favoring the combined Schroth Method plus core stabilization protocol across most functional and quality-of-life outcomes. The largest additional proportional benefit was observed for the Sorensen test, where Group A improved by 53.3% compared with 16.2% in Group B, yielding a 37.1% response gradient. Chest mobility also showed a greater proportional increase in Group A than Group B, with improvements of 41.7% and 24.5%, respectively. SRS-22r pain, mental health, self-image, and function similarly showed larger proportional gains in Group A. Cobb angle reduction was substantial in both groups, with proportional reductions of 55.4% in Group A and 56.2% in Group B; therefore, the derived proportional gradient for Cobb angle slightly favored Group B by 0.9%, although the absolute reduction remained numerically similar between groups. This pattern suggests that the main added value of core stabilization may be more evident in endurance, chest expansion, and patient-reported functional domains than in proportional radiographic correction alone.

DISCUSSION

This randomized controlled trial evaluated the comparative effects of the Schroth Method with and without additional core stabilization exercises in individuals with idiopathic scoliosis. The findings demonstrated clinically relevant improvement in both groups across radiographic, functional, respiratory, and patient-reported outcomes after 10 weeks of supervised rehabilitation. Cobb angle decreased substantially in both groups, while lumbar extensor endurance, chest mobility, and SRS-22r domains improved over time. When the pattern of response was examined across outcomes, the combined intervention showed clearer additional benefit for Sorensen test performance, chest mobility, pain, self-image, mental health, and functional domains, whereas proportional Cobb angle reduction was broadly comparable between groups. This suggests that adding core stabilization to Schroth-based rehabilitation may produce its strongest incremental effect on functional endurance, thoracic expansion, and quality-of-life outcomes rather than on radiographic correction alone.

The observed reduction in Cobb angle in both groups supports the therapeutic relevance of scoliosis-specific exercise in conservative idiopathic scoliosis management. The Schroth Method is designed to address the three-dimensional nature of scoliosis through active postural correction, spinal elongation, rotational angular breathing, de-rotation strategies, and sensorimotor retraining. These mechanisms may reduce asymmetric trunk loading and improve the patient's ability to maintain corrected alignment during static and dynamic activities. Previous trials and reviews have similarly reported that Schroth-based exercise can improve radiographic parameters and trunk rotation in adolescent idiopathic scoliosis, although the magnitude of Cobb angle change may vary according to curve severity, skeletal maturity, adherence, treatment duration, therapist expertise, and whether bracing or other conservative interventions are used concurrently (4,5,15,20,21,35,40,42,44). In the present study, both groups achieved marked Cobb angle reduction over 10 weeks, indicating that structured Schroth exercise itself contributed meaningfully to radiographic improvement.

Although the between-group Cobb angle comparison at the 10th week was statistically significant in the manuscript tables, interpretation should remain cautious because the reported 10-week value for Group A is inconsistent across the table and narrative. The formal Results table reports Group A as 12.000 ± 2.496°, whereas another narrative section reports 9.286 ± 2.496°. This discrepancy has direct implications for the magnitude and direction of treatment effect. Using the formal table value, both groups showed very similar baseline-to-10-week absolute reductions, and proportional improvement was slightly greater in Group B. Therefore, the present discussion interprets Cobb angle improvement as substantial in both groups and avoids claiming definitive radiographic superiority for the combined intervention until the original statistical output is verified. This correction is important because clinically meaningful interpretation of scoliosis outcomes depends not only on p-values but also on measurement precision, baseline comparability, change magnitude, and whether observed differences exceed expected radiographic measurement error (18,45).

The Sorensen test findings support the added value of core stabilization for trunk endurance. Group A improved from 2.002 ± 0.836 at baseline to 3.069 ± 1.029 at the 10th week, whereas Group B improved from 2.201 ± 0.921 to 2.557 ± 0.950. The larger improvement in the combined group is clinically plausible because core stabilization exercises directly target the neuromuscular control and endurance of the deep trunk stabilizers, including the multifidus, transversus abdominis, spinal extensors, pelvic stabilizers, diaphragm, and abdominal wall. These muscles contribute to segmental spinal stability and sustained postural correction, which are highly relevant in idiopathic scoliosis, where asymmetrical muscle activity, reduced trunk endurance, and impaired postural control may coexist with structural deformity (7,16,23,24,29,30). The findings are also consistent with previous work suggesting that stabilization-based programs may improve trunk muscle endurance and functional control in adolescents with idiopathic scoliosis, particularly when integrated with scoliosis-specific corrective exercise rather than used in isolation (23,24,30).

Chest mobility improved in both groups, with a greater mean increase in the combined-intervention group. Group A increased from 3.361 ± 1.071 cm at baseline to 4.763 ± 0.880 cm at the 10th week, while Group B increased from 3.408 ± 0.882 cm to 4.244 ± 0.917 cm. This finding is clinically relevant because scoliosis can influence thoracic mechanics, rib mobility, respiratory excursion, and trunk expansion, especially when spinal rotation and thoracic asymmetry are present. Schroth exercises incorporate rotational angular breathing and concave-side expansion, which may enhance chest wall mobility by encouraging directed thoracic expansion and improved postural alignment. The additional benefit observed in Group A may be explained by improved coordination between respiratory and trunk stabilizing muscles, particularly the diaphragm, abdominal wall, and pelvic stabilizers, which contribute to both breathing mechanics and postural control (14,16,17,36). Therefore, combining breathing-oriented scoliosis-specific correction with progressive stabilization may provide a more integrated approach to respiratory and trunk function.

The SRS-22r findings further support the functional and psychosocial relevance of combined rehabilitation. Group A demonstrated significant improvement in function, pain, self-image, and mental health domains, while Group B showed improvement in pain, self-image, and mental health but not in function. The greatest improvements in Group A were observed in mental health and pain, which is meaningful because scoliosis affects not only spinal alignment but also body image, confidence, activity tolerance, and emotional well-being during adolescence. Improvements in self-image and mental health may reflect better postural awareness, perceived control over deformity, reduced discomfort, and greater confidence in physical function. Prior literature has emphasized that patients with adolescent idiopathic scoliosis may perceive meaningful benefit from exercise-based care even when radiographic changes are modest, supporting the importance of including patient-reported outcomes alongside Cobb angle in conservative scoliosis trials (4,6,40,48).

The pattern of results suggests that the addition of core stabilization may improve the functional capacity needed to maintain corrected posture during daily activity. Schroth exercises provide curve-specific postural correction and breathing-based de-rotation, whereas core stabilization may enhance the muscular endurance required to sustain those corrections. This complementary mechanism may explain why the combined group showed clearer benefit in endurance, chest mobility, and quality-of-life domains. Similar reasoning has been proposed in studies comparing scoliosis-specific exercises, core stabilization, asymmetric spinal stabilization, and conservative rehabilitation combinations, where multimodal programs often appear more effective for functional outcomes than single-component interventions (9,16,23,24,28,30,47). However, because the present trial did not include long-term follow-up, it remains uncertain whether these improvements persist after supervised treatment ends or whether continued home exercise is required to maintain gains.

The findings should be interpreted in light of several limitations. First, the study was conducted at a single center, which may limit generalizability to other clinical settings, therapist expertise levels, and patient populations. Second, participants and therapists could not be blinded because of the nature of the interventions, creating a possible performance or expectation effect, although assessor blinding reduced measurement bias. Third, adherence to home-based posture correction, unsupervised daily activity, and psychological factors were not fully controlled, which may have influenced functional and quality-of-life outcomes. Fourth, the 10-week follow-up period was sufficient to detect short-term treatment response but not long enough to determine durability of improvement, curve progression, or long-term avoidance of more intensive interventions. Fifth, the statistical analysis would be strengthened by reporting group × time interaction effects, between-group differences in change scores, 95% confidence intervals, and intention-to-treat analysis. Finally, the internal inconsistency in the reported Group A 10-week Cobb angle must be resolved before final publication, as it affects the interpretation of radiographic superiority.

Despite these limitations, the study contributes clinically useful evidence by examining a combined rehabilitation strategy that integrates scoliosis-specific correction with trunk stabilization. The results indicate that both Schroth Method alone and Schroth Method with core stabilization can improve outcomes in idiopathic scoliosis over 10 weeks. The combined protocol appears particularly advantageous for lumbar extensor endurance, chest mobility, and patient-reported domains, suggesting that core stabilization may strengthen the functional foundation required to sustain scoliosis-specific postural correction. Future multicenter trials with larger samples, longer follow-up, standardized exercise adherence monitoring, predefined primary endpoints, and complete reporting of confidence intervals and effect sizes are recommended to confirm the durability and clinical significance of these findings.

CONCLUSION

The study showed that both the Schroth Method alone and the Schroth Method combined with core stabilization exercises produced significant short-term improvements in patients with idiopathic scoliosis. Cobb angle decreased substantially in both groups, while lumbar extensor endurance, chest mobility, and SRS-22r quality-of-life domains improved over the 10-week intervention period. The addition of core stabilization exercises appeared to provide greater functional benefit, particularly for trunk extensor endurance, chest mobility, pain, self-image, mental health, and functional quality-of-life outcomes. These findings support the clinical value of integrating progressive core stabilization into scoliosis-specific rehabilitation; however, final interpretation of radiographic superiority should be made only after verification of the inconsistent 10-week Cobb angle value in the original statistical output.

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