Three-dimensional Postural Correction in Idiopathic Scoliosis with Clinical Outcomes of PSSE-Schroth Exercises

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Abstract

Introduction: Adolescent idiopathic scoliosis is a three-dimensional deformity of the spine that impairs physical function, posture, and quality of life. Conservative treatment options, especially PSSE-Schroth exercises, are gaining increasing clinical relevance. However, evidence from Southeastern Europe remains limited. *Objectives:* To assess the clinical efficacy of a standardized PSSS-Schroth program on posture, pelvic symmetry, and functional status in adolescents with idiopathic scoliosis through a prospective, clinically applicable observational study. *Methods and materials:* This single-center study included 16 participants (12 women, 4 men; mean age 18.6 ± 12.4 years) with idiopathic scoliosis (Cobb angle ≤ 40°) who underwent 3-6 months of individualized PSSE-Schroth under the supervision of a certified physiotherapist. Outcome measures included clinical postural assessment, pelvic imbalance, functional mobility, and limited radiographic evaluation. Descriptive statistics and subgroup analyses were used to assess pre-intervention outcomes. *Results:* Participants demonstrated significant improvements in scapular symmetry, trunk alignment, and reduction in rotational deformity, as documented by clinical photographs and functional reassessment. Although full radiographic follow-up was limited, individual case comparisons demonstrated stability or regression of curve severity in those who adhered to the exercises. The majority of adolescents (81.25%) demonstrated postural correction regardless of the use of a prosthesis. Statistical analysis showed a potential relationship between the Riser grade and the type of scoliosis ($p = 0.057$). No significant age or gender differences were observed in the pelvic alignment categories. *Discussion:* This study showed that a structured PSSE-Schroth program can improve posture and trunk symmetry in persons with idiopathic scoliosis, even within a relatively short intervention period. These results are well connected with existing evidence supporting the conservative role of PSSE-Schroth in scoliosis treatment, although the lack of a control group and small sample size limit the generalizability. *Conclusions:* This study defines the value of PSSE-Schroth exercises in the conservative treatment of idiopathic scoliosis. Despite methodological limitations, the results show that PSSE-Schroth can produce measurable

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improvements in posture and spinal alignment, even in a short treatment period. Further research is needed to confirm these findings and optimize standardized protocols.

Keywords: *adolescent idiopathic scoliosis; PSSE-Schroth exercises; physiotherapy; postural balance; spinal deformities; scoliosis*

Introduction

Idiopathic scoliosis is a complex three-dimensional deformity of the spine and trunk, which is primarily diagnosed in healthy children and adolescents during growth [1]. This condition is characterized by lateral deviation of the spine with a Cobb angle exceeding 10 degrees and is often manifested by vertebral rotation and altered sagittal alignment [2, 3]. Although the etiology of scoliosis is unknown, the progression of idiopathic scoliosis is influenced by a number of factors, such as growth dynamics, neuromuscular control, biomechanical imbalances, and genetic predispositions [4, 5]. The majority of diagnosed scoliosis belongs to adolescent idiopathic scoliosis, which mostly affects women during the intense growth spurt of puberty [6]. Although mild scoliosis curves may remain stable, progressive curves can cause major structural, functional, and psychosocial consequences for children and adolescents [7, 8]. If scoliosis is left untreated, it will impair the mobility of the spine, indirectly impair breathing, and greatly alter body image, thus reducing the overall quality of life [9]. Early diagnosis and conservative treatment are very important to avoid surgery, especially for patients at risk of rapid progression during intense pubertal growth spurts [10].

When it comes to the conservative treatment of scoliosis, the specific Schroth-PSSE exercises, which have recently been increasingly used by physiotherapists, are of great importance [11, 12]. Among them, the Schroth method developed in the 1920s continues to be refined with various structured modalities and combinations of it such as BSPTS and Schroth Best Practice, which are also some of the most widely researched and clinically implemented modalities as a choice of exercises for scoliosis [13, 14]. The PSSE-Schroth modality generally focuses on personalized three-dimensional spinal correction with emphasis on self-stretching, rotational breathing, focused muscle activation of specific muscles affected by scoliosis, and postural reeducation. These principles aim to improve spinal stability, reduce deformity for further progression, and integrate corrective postures into the daily functional activities of the persons affected by this condition [15, 16]. The implementation of PSSE-Schroth exercises in practice has shown positive results, especially in adolescents with mild to moderate scoliosis [17, 18]. Despite the increasing interest in PSSE Schroth exercises, scientific data from Southeast Europe remains limited [19].

This study attempts to address this scientific paucity of these exercises by evaluating the practical efficacy of a standardized PSSE-Schroth method in 16 patients, mostly adolescents, diagnosed with idiopathic scoliosis. The results were analyzed based on radiological images, posture, functional mobility, and several quality-of-life indicators. The research aims to contribute to evidence-based

practice and to emphasize the role of individualized, multidimensional physiotherapy in the conservative treatment of scoliosis.

Materials and methods

Study design and setting

This observational study was conducted to assess the effectiveness of PSSE specific exercises based on the Schroth method in individuals with idiopathic scoliosis. The study followed a prospective cohort design and was implemented within the framework of physiotherapy and rehabilitation under the supervision of a physiotherapist specialized in rehabilitation in orthopedics, traumatology and surgery. The study covered a period of 6 months with standardized baseline assessments and post-intervention assessments.

Participants

16 participants with diagnosed scoliosis were included in this study. The initial study design consisted of adolescents in the majority (n = 13; 81.25%), with a minority of slightly older participants (n = 3; 18.75%). Participants were recruited by clinical referral and screened based on inclusion and exclusion criteria. Inclusion criteria were definitively diagnosed idiopathic, functional, or combined scoliosis, age between 9 and 55 years, Cobb angle ≤ 40° at the time of enrollment, no previous spinal surgery, and willingness and ability to participate in the PSSE-Schroth exercise program throughout the entire intervention period. Exclusion criteria from were neuromuscular or congenital scoliosis with associated structural abnormalities of the spine, severe cognitive, psychiatric, or motor disorder that prevents active participation in the program, and postoperative spinal fusion or limited spinal mobility.

Intervention protocol

All study participants underwent a standardized PSSE-Schroth method administered by a licensed Schroth-certified physical therapist. The program was individualized according to the type of the curvature of the patient (3C+, N3N4, 4C) and postural compensations, following established Schroth classification models. Participants attended 2-3 treatments per week, each lasting 45-60 minutes, for a period of 3-6 months. The exercise components focused on 3D automatic correction, i.e. stretching and repositioning of the spine in all three anatomical planes; rotational angular breathing with breathing techniques to expand concave areas and derotate the spine, asymmetrical exercises targeting the deep muscles - stabilizers of the spine, training patients to implement corrected posture during daily activities (when sitting, standing, walking, etc.). Progress was individualized and monitored by the physiotherapist based on weekly visual and functional reassessments.

Outcome measures

The protocol for assessing structural and functional outcomes before and after the intervention was used. Before treatment, a radiological assessment was initiated with an emphasis on standard

anteroposterior radiographs of the entire spine, which were used to measure Cobb angles. The apical vertebrae and the type of curvature were also documented. The Risser sign, a marker of skeletal maturity, was also evaluated to assess the risk of progression. This was assessed to assess skeletal maturity and risk of progression. For postural analysis, clinical photographs were taken in the frontal and sagittal planes to visually assess asymmetries. Pelvic balance was also assessed, with palpation and visual inspection for any lateral or rotational pelvic tilt. Tests for range of motion, trunk endurance, and postural control tasks were used to assess functional capacity. Regarding quality of life, subjective measures related to pain, daily functioning, and discomfort were collected through structured questionnaires adapted to the population included in the study.

Subgroup classification

Participants were stratified based on age group, i.e. adolescents (<18 years) versus adults, by gender (12 females - 75% and 4 males - 25%), by use of orthoses (4 wore orthopedic orthoses (25%), 12 did not wear orthoses (75%), by pelvic alignment, of which 6 were unbalanced, 6 with a left-sided tilt, and 4 with a right-sided tilt, according to the Risser sign - 70% had a grade 4 (close to skeletal maturity), while the rest had a grade 3 or 5.

Procedure

Initially, baseline assessments were performed before the method was implemented. Periodic controls were performed every 4 weeks with visual checks of posture and feedback from the patients. The final assessment included comparative radiological imaging, functional re-evaluation, and quality of life re-assessment. All assessments were standardized, performed by the same physiotherapist in order to reduce inter-rater variability.

Statistical analysis

Given the observational nature of the study and the limited sample size (N = 16), a combination of descriptive and nonparametric statistical methods was used to evaluate the PSSE-Schroth results. Categorical variables were summarized using frequencies and percentages, while continuous variables were expressed as means and standard deviations. Radiological and clinical outcomes were compared descriptively across time points, supported by narrative interpretation and visual case analysis. Inferential analyses were selectively applied to examine potential associations between variables of clinical relevance. A chi-square test of independence was conducted to explore the relationship between scoliosis type and skeletal maturity, yielding a nearly significant result [$\chi^2(4, N = 11) = 9.17$, $p = 0.057$], indicating a possible developmental relationship. Kruskal-Wallis testing was used to evaluate age differences across pelvic alignment subgroups, which did not reach statistical significance [$H(2) = 0.22$, $p = 0.894$]. Associations between pelvic imbalance and gender were similarly assessed using chi-square testing [$\chi^2(2, N = 16) = 0.44$, $p = 0.801$], indicating the absence of a significant relationship. Due to sample size limitations and heterogeneity in clinical profiles, advanced multivariate analyses were not performed. Instead, individualized visual

assessments and structured photographic comparisons were integrated to support clinical interpretation. All statistical calculations were performed using Microsoft Excel with manual validation of output to ensure data integrity.

Ethical considerations

The study was conducted in accordance with the ethical standards laid down in the Declaration of Helsinki and was approved by the Ethics Committee of Higher Medical School - Bitola, University St. Kliment Ohridski Bitola. All participants (or their legal guardians for minors) provided written informed consent before enrollment. Confidentiality and anonymity were maintained throughout the research.

Results

Table 1. Distribution of participants by age and gender

Gender	n	%	Age of the participants	Mean age ± SD
Female	12	75.0%	9–55	18.3 ± 12.9
Male	4	25.0%	10–16	19.5 ± 11.1
Total	16	100.0%	9–55	**18.6 ± 12.4**

A total of 16 participants were included in this study (12 women and 4 men) based on Table 1. The majority were women - 75% of the total sample. The age of the participants ranged from 9 to 55 years. The average age of the respondents was 18.6 years with a standard deviation of ±12.4 years. In women, the average age was 18.3 ± 12.9 years, while in men it was slightly higher, 19.5 ± 11.1 years. These results indicate an increased percentage of adolescents with scoliosis, especially in women, which is in line with global epidemiological trends in idiopathic scoliosis.

Table 2. Distribution of Risser grades by the type of scoliosis among participants

Type of scoliosis	Risser 3	Risser 4	Risser 5	Not reported	Total
N3N4	0	6	0	0	6
3C+	0	2	1	0	3
3C–	1	0	1	0	2
4C+	0	0	0	1	1
4C–	0	0	0	1	1
3C+ S type	0	0	0	1	1
N3N4–	0	0	0	2	2
Total	1	8	2	5	16

Table 2 shows the distribution of Risser grades by scoliosis type, including participants with missing skeletal maturity data. Of the 16 participants, Risser grade was documented in 11 individuals (68.75%), while in 5 cases (31.25%) this value was not reported due to missing radiographs. Missing data were primarily associated with less common curve subtypes such as 4C+, 4C−, and N3N4−. Most of the recorded cases fell under Risser grade 4 (n = 8), especially those with N3N4 scoliosis. These omissions were excluded from the inferential statistics, but are shown here to provide a comprehensive overview of the data set. In the context of the table, the relationship between scoliosis type and skeletal maturity, as assessed by the Rieser scale, was also examined with a chi-

square test of independence. The test approached statistical significance, with $\chi^2(4, N = 11) = 9.17$, $p = 0.057$, indicating a possible association between specific curvature patterns and developmental stage. Although not statistically significant at the 0.05 level, the result reflects one that may have clinical relevance if a larger number of subjects were considered.

Table 3. Distribution of pelvic imbalance, gender and age among participants

Pelvic imbalance	Gender	n	Mean age	SD	Min age	Max age
Left Tilt	Female	5	18.8	10.7	14	38
	Male	1	10.0	–	10	10
None (Neutral)	Female	4	23.8	20.8	13	55
	Male	2	15.0	1.4	14	16
Right Tilt	Female	3	14.3	1.5	13	16
	Male	0	/	/	/	/
Total		16	/	/	/	/

Table 3 presents the combined distribution of pelvic imbalance, gender, and participant age. Left-sided pelvic tilt was most frequent (n = 6), followed by neutral alignment (n = 6) and right-sided tilt (n = 4). Among females, the highest mean age was observed in those with no pelvic imbalance (23.8 ± 20.8 years), while males showed a more restricted age range, with no male participants presenting right-sided tilt. A Kruskal–Wallis test revealed no statistically significant difference in age across pelvic alignment groups, $H(2) = 0.22$, $p = 0.894$, and a chi-square test indicated no significant association between pelvic imbalance and gender, $\chi^2(2, N = 16) = 0.44$, $p = 0.801$.

Figure 1. Postural and rotational improvement in a patient with idiopathic scoliosis after six months of PSSE-Schroth exercises

According to Figure 1, the first four images on the left (two standing and two forward-bending views) shows the posture of the patient prior to therapy (documented on August 5th, 2024). Notable findings include scapular asymmetry, visible thoracic convexity, and pronounced rotational deformity during the Adam's forward bend test. The three images on the right (two standing and one forward-bending) shows the posture of the patient after six months of therapy (documented

on February 11th, 2025), showing improvement in spinal alignment, shoulder symmetry, and reduction in trunk rotation.

Figure 2. Objective and clinical documentation of scoliosis management in a female patient with PSSE-Schroth exercises

Based on Figure 2, the upper image shows the baseline standing anteroposterior radiograph (prior to therapy), indicating a primary thoracic curve of 21°, with compensatory upper and lower curvatures of 18° and 8°, respectively. The lower two images were taken after completion of a six-month PSSE-Schroth exercises, on March 26th, 2025. Postural assessment showed improved scapular symmetry, visible reduction in trunk rotation during the Adam's forward bend test, and normalization of spinal axis alignment.

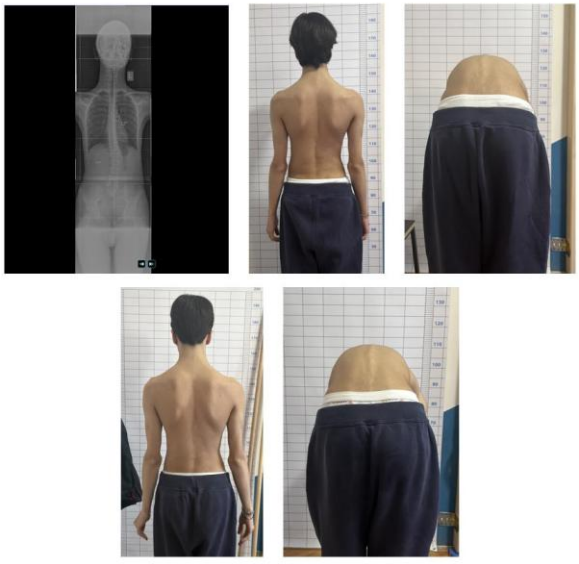

Figure 3. Radiographic and clinical improvement in a male patient with idiopathic scoliosis after PSSE-Schroth exercises

Figure 3 shows the documentation of pre- and post-intervention changes in a male patient with idiopathic scoliosis after PSSE-Schroth-based physiotherapeutic management. The upper image shows a full-spine anteroposterior radiograph obtained prior to therapy, demonstrating a primary thoracic curve of 23° and compensatory curvature below. The lower images represent the patient's clinical posture after the exercises, documented on March 4th, 2025. Improvements are observed in scapular symmetry and spinal axis alignment. The forward bending test further shows reduced rib hump prominence, suggesting successful de-rotation and muscular rebalancing through PSSE principles.

Figure 4. Radiological and postural correction in a male patient with idiopathic scoliosis after PSSE-Schroth exercises

Based on Figure 4, which presents both radiographic and clinical images of a male patient, substantial postural improvements were observed after Schroth-based PSSE exercises. The initial radiographs clearly show spinal curvature and vertebral rotation in both thoracic and lumbar regions.

Figure 5. Combined orthotic and physiotherapeutic correction in a female patient with idiopathic scoliosis

After the intervention period with exercises, clinical photographs showed correction in trunk alignment and visible reduction in rib prominence during forward bending. Also, scapular symmetry improved significantly, suggesting effective muscular re-education and de-rotation through personalized PSSE exercise.

Based on Figure 5, the patient showed significant clinical improvement after combined treatment approach involving orthotic support and PSSE-Schroth exercises. The initial radiograph confirmed a double-curve scoliosis pattern, with a right thoracic Cobb angle of 32° and a left lumbar curve of 23°. Clinical images from February 4th, 2024, showed pronounced shoulder asymmetry, waistline imbalance, and a marked rib prominence during the Adams forward bend test (second two photographs). Notably, these postural irregularities were present despite the use of a dynamic orthosis. After several weeks of combined intervention, follow-up photographs showed improved trunk alignment, reduced rotational deformity, and better scapular and pelvic balance.

Discussion

The aim of this study was to evaluate the clinical effects of PSSE-Schroth-based exercises in adolescents diagnosed with idiopathic scoliosis. Using pre- and post-intervention radiographic, observational, and postural assessments, this study investigated the structured, noninvasive treatment in preventing curve progression and improving postural symmetry. The results of this study are consistent with many studies supporting the efficacy of PSSE-Schroth-based programs in managing mild to moderate idiopathic scoliosis during the growth spurt. In addition, the inclusion of visual documentation from real-life cases and individualized treatment responses allow for interpretation beyond radiographic outcomes alone. This discussion integrates the results of the study with the existing literature, highlights potential mechanisms of benefit from this exercise method, and highlights both the strengths and weaknesses of this Schroth modality.

The results of this study are consistent with and complement those published by Kuru et al. (2015), who investigated the efficacy of three-dimensional Schroth exercises in adolescents with idiopathic scoliosis through a randomized controlled trial. In their study, significant improvements were observed in Cobb angle, rotational deformity, waist asymmetry, and rib prominence, especially in the group receiving supervised Schroth therapy in a clinical setting. In contrast, no change was observed in quality-of-life outcomes, and curve progression was evident in the untreated control group. Our study demonstrated postural and structural improvements in several patients who underwent an individualized PSSE-Schroth method, as evidenced by a reduction in scapular and pelvic asymmetry, normalization of trunk alignment, and reduced rotational deformity - documented through visual and radiographic analyses. Although our study was not designed as a randomized trial and did not remeasure Cobb angles after intervention in all cases, consistent clinical trends indicate stabilization or improvement of spinal curvature when exercises were performed regularly under the supervision of a physiotherapist [20].

A recent randomized clinical trial supports the efficacy of Schroth exercises in adolescents with idiopathic scoliosis. Their results showed significant improvements in Cobb angle, trunk rotation, and quality of life after 12 months of combined orthopedic therapy and Schroth therapy, with benefits persisting after 18 months. These results support the idea of a dose-response relationship between exercise duration and treatment efficacy. Although our study did not evaluate changes in Cobb angle radiographically in all cases, the observed visual and functional improvements in a shorter intervention period are consistent with their conclusion that supervised Schroth-based therapy can produce significant postural correction even within a few months of implementation [21]. Another research further supports the utility of three-dimensional Schroth exercise therapy in adolescents with idiopathic scoliosis. Their data demonstrated improvements in Cobb angle, vital capacity, muscle strength, and posture across multiple time points—specifically, a reduction from 26.1° to 17.85° in Cobb angle over one year. These findings highlight the multidimensional benefits of structured Schroth programs that combine supervised clinical phases with home-based continuity. Although our study did not quantify pulmonary function or muscle strength, the observed improvements in posture and visual spine posture over a shorter time interval remain consistent with the targeted outcomes reported in their study [22].

A randomized controlled trial provides strong evidence supporting the additive value of PSSE-Schroth over standard care in adolescents with idiopathic scoliosis. Their results showed statistically significant improvements in Cobb angle reduction at six months, with between-group differences reaching -4.1° in the largest curve and -5.8° in the sum of curves for those adhering to the protocol. These results were achieved through a structured combination of supervised sessions and daily home exercises. Although this study did not include a control group or remeasure Cobb angles in all cases, similar trends were observed through clinical photographs and postural assessments, particularly in shoulder alignment, trunk symmetry, and reduction. Despite growing interest in Schroth-based interventions, the review emphasized that many existing studies lacked standardized exercise labeling, prospective protocol registration, and adherence monitoring - factors that compromise the strength of evidence [23].

The recent systematic review and meta-analysis concluded that PSSE-Schroth is more effective than other non-surgical treatments including general exercise and bracing in reducing Cobb angle and improving pain, self-image, and mental health in adolescents with idiopathic scoliosis. These findings strongly support PSSE-Schroth as a first-line intervention, especially in patients with Risser grade 0-3 or no prior brace treatment. In alignment with their conclusions, our study showed functional and postural improvements in non-braced adolescents defining the growing consensus on the efficacy of PSSE-Schroth in early, conservative scoliosis management [24].

Limitations and future directions

Despite the favorable results observed in this study, several limitations should be acknowledged. First, the study used an observational design without a control group, which limits causal inference and limits the ability to compare the PSSE-Schroth modality with other therapeutic modalities.

Second, the small sample size (N = 16) reduces the statistical power and generalizability of the results, especially in light of the heterogeneity in patient age, curve type, and use of orthoses, but for justified reasons since North Macedonia is a country with a small population, especially those who have heard of or are being treated with this type of exercises. Third, although postural and visual improvements were well documented through clinical photographs and case-based follow-up, radiographic reassessments such as Cobb angle measurements were not performed for all participants, which limits the objective quantification of curve reduction. On the other hand, the absence of standardized outcome measures for quality of life and functional capacity reduces the comparability of results with previous high-quality studies. Reliance on visual assessments and descriptive analyses may also introduce subjective bias. Future research should aim to address these limitations through well-powered, randomized controlled trials that include control groups, prospective enrollment, standardized Schroth classification protocols, and appropriate follow-up. Inclusion of validated outcome measures, radiographic re-evaluation, and objective functional tests will increase the rigor and reproducibility of results. Multicenter studies in Southeastern Europe and other underrepresented regions are needed to expand the worldwide evidence base and support culturally sensitive implementation of PSSE-Schroth programs in practice.

Conclusions

This study adds to the growing body of evidence supporting the relevance of PSSE-Schroth exercises as a conservative treatment for adolescent idiopathic scoliosis. Through individualized 3D postural correction, rotational breathing, and neuromuscular retraining, PSSE-Schroth demonstrates measurable improvements in postural symmetry, scapular alignment, and trunk rotation. These visual and functional benefits observed even in a relatively short intervention period mirror the results of more powerful randomized studies and systematic reviews reporting stabilization of scoliosis curves and improved quality of life in adolescents who adhere to Schroth protocols. While the nonrandomized study design and small sample size warrant cautious interpretation, its methodological transparency, structured clinical implementation, and consistent patient follow-up represent defining strengths—especially in the context of Southeastern Europe where access to structured scoliosis rehabilitation remains limited. In the absence of widespread surgical indications, these exercises offer a low-risk, patient-centered, and potentially impactful strategy for managing scoliosis progression during critical growth phases. Future studies are essential to further validate and generalize these findings on a larger scale.

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