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ORIGINAL ARTICLE

Physiotherapeutic Scoliosis-Specific Exercises (PSSE-Schroth) can reduce the risk for progression during early growth in curves below 25°: prospective control study

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ABSTRACT

BACKGROUND: The main treatment aim in mild scoliosis is to prevent progression and if possible, to avoid bracing. Physiotherapeutic Scoliosis Specific Exercises (PSSE) are curve pattern specific exercises, based on 3D self-correction and activities of daily living training.
AIM: The objective of this study was to evaluate the efficacy of PSSE - Schroth, as an exclusive treatment, during the riskiest period of rapid growth.
DESIGN: Prospective control study.
SETTING: Outpatient treatment.
POPULATION: Adolescents with scoliosis.
METHODS: One hundred and sixty-three patients (148 girls,15 boys; mean age 12.6 years, Risser sign 1.1, thoracic (Th) Cobb angle 20.8° and lumbar/thoracolumbar (L/TL) Cobb angle 20.7°) performed PSSE - Schroth exercises in our clinic. They were asked to regularly attend supervised sessions and to follow a home-program at least 5 times per week. Our inclusion criteria were Cobb angle 15°-25°, Risser 0-2 and angle trunk rotation (ATR) >5°, measured by scoliometer. The outcome parameters were the Cobb angle before and after the intervention (improvement or progression were defined as angle difference more than 5°) and the number of patients that finally needed a brace. Average follow up time was 29.4 months. Control group was consisted of 58 patients (54 girls, 4 boys; mean age 13.1 years, Risser sign 0-2, Th Cobb 19.4°, L/TL Cobb 19.2°), that were retrospectively analyzed and performed general or no exercises. Compliance was self-reported. Statistical analysis was performed by paired t-test.
RESULTS: For PSSE - Schroth group, 103 patients (63.2%) remained stable, 39 (23.9%) improved and 21 (12.9%) worsened. The success rate (87.1%) was significantly higher compared to Control group (P=0.002), where 15 subjects (25.9%) were stable and 43 (74.1%) worsened. Similarly, 16 patients (9.8%) from PSSE - Schroth group finally needed a brace, while 39 (67.2%) from control group (P=0.01).
CONCLUSIONS: PSSE - Schroth reduced the risk of progression in Adolescent Idiopathic Scoliosis (AIS) patients, during early growth. Our results are in accordance with the recently published literature, showing the effectiveness of PSSE and their superiority compared to general exercises or natural history.
CLINICAL REHABILITATION IMPACT: Scoliosis specific exercises can be the first step of scoliosis treatment in mild curves, to avoid progression and bracing.

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KEY WORDS: Scoliosis; Exercise; Braces.

Early detection of scoliosis during adolescence is crucial to decrease the likelihood of curve progression to the point of requiring surgical management, so the implementation of effective screening programs is recommended by most of the scientific societies.[1] Physiotherapeutic Scoliosis Specific Exercises (PSSE) have been proposed as the first step of non-operative therapy to avoid progression and potentially to reduce brace prescription.[2] Brace treatment is indicated for moderate curves above 25° with residual growth.[3]

Negrini *et al*.[4] found that Scientific Exercises Approach to Scoliosis (SEAS) was superior to usual physiotherapy, decreasing the brace prescription rate. Monticone *et al*.[5] used active self-correction and task-oriented specific exercises in a Randomized Control Trial (RCT) to prove their superiority against traditional exercises. Zapata *et al*.[6] in a prospective study found less curve progression in PSSE group compared to observation group, but bracing rate was almost similar for both groups at 1-year follow-up.

Recent systematic reviews found that PSSE can have a positive effect on Cobb angle, Angle of Trunk Rotation (ATR) and Quality of Life (QOL) measurements.[7, 8] However, Fan *et al*.[9] and Zwou *et al*.[10] agreed that the quality of evidence was insufficient to draw safe conclusions about their effectiveness, due to lack of long-term follow up, potential risk of bias and marked heterogeneity.

PSSE are curve-pattern specific exercises based on three-dimensional self-correction and patient education for activities of daily living training.[2] Berdishevsky *et al.* reviewed seven major PSSE Schools, who fulfilled these baseline characteristics.[11] The Schroth-based techniques included International Schroth Scoliosis Treatment (ISST), Schroth Best Practice and Barcelona Scoliosis Physical Therapy School (BSPTS).[11] This manuscript introduces the PSSE-Schroth method, which is the most recent development in scoliosis specific exercises field, using a new classification, innovative concepts of corrections, muscle activation and mobilizations.

Several studies reported change in Cobb angle as the primary outcome parameter but this may not be a sufficient outcome measure in scoliosis studies a statistically significant changes in Cobb angle may not be consistent with meaningful clinical change. Percentage of brace prescription can be considered as more clinically important value.[4] The main aim of the present study was to investigate the effectiveness of PSSE-Schroth as an exclusive treatment for scoliotic curves during early growth, by evaluating the clinically meaningful change in Cobb angle as well as frequency of referral for brace prescription.

Materials and methods

This was a Prospective Control Study. Our hypothesis was that PSSE-Schroth exercises can halt progression during early growth spurt in mild scoliosis with Cobb angle <25°. All our subjects visited our clinic and were advised to follow a program of scoliosis specific exercises with PSSE-Schroth method, as sole treatment for their scoliosis. Ethical approval was obtained by the International Hellenic University, Department of Physiotherapy, Faculty of Health Sciences Ethics Committee (approval number EC-01/2023), following the ethical standards as laid down in the 1964 Declaration of Helsinki. Level of Evidence was II according to Oxford Center for Evidence-Based Medicine.[12]

Subject's recruitment started in our clinic, from April 2017 and stopped December 2022. Every participant and their family received a research information sheet, and a consent form was signed by the parents to allow the use of their child's clinical data for research purposes. All the data was collected from our prospective database, therefore all eligible patients, who fulfilled the inclusion criteria were enrolled in the study, to avoid selection bias.

Inclusion criteria

Our inclusion criteria were Cobb angle 15°-25° (at least for one curve), age >10 years, Risser sign 0-2, less than 1-year post-menarche and Angle Trunk Rotation (ATR) >5°, measured by scoliometer. The rationale for ATR >5° was to ensure that our sample was at higher risk of progression, excluding functional scoliosis with minimal or no rotation. We chose 5° instead of 7° for ATR, because in many lumbar curves the trunk rotation can be less than 7° but without already marked vertebra rotation and deformity. A forward bending test performed both in standing and sitting position, to ensure that no real leg length discrepancy would affect the measurement.

Patients with congenital, neuromuscular, and syndromic scoliosis were excluded, as well as patients that already wore a brace. Risser sign does not always represent the real bone age, so we decided to exclude girls with more than 1 year after first menstruation, to ensure only patients with significant risk of progression.[13]

PSSE - Schroth method

PSSE-Schroth method is a newly developed program of curve pattern scoliosis specific exercises, based on original Schroth method,[14] using 3D autocorrection, self-elongation, corrective breathing, and activities of daily living training. A modified Schroth classification was introduced

to classify scoliosis curve types. A pilot study was performed between the authors to test the inter-rater and intra-rater reliability of the new classification, showing excellent results (ICC=0.9).

PSSE-Schroth classification includes eight different curve types, which are described in Figure 1. The classification is determined by the therapist following a decision tree algorithm, answering three questions and accordingly treat their patients (Figure 2):

- question 1: is there a structural thoracic scoliosis?;
- question 2: where is the pelvis in relation to the trunk in frontal plane?;
- question 3: is overcorrection allowed for the main curve?

The therapist can answer questions 1 and 2, based mainly on clinical observation, but for question 3 radiological and prognostic criteria must be applied. The purpose of PSSE-Schroth classification is to get the maximum of cor-

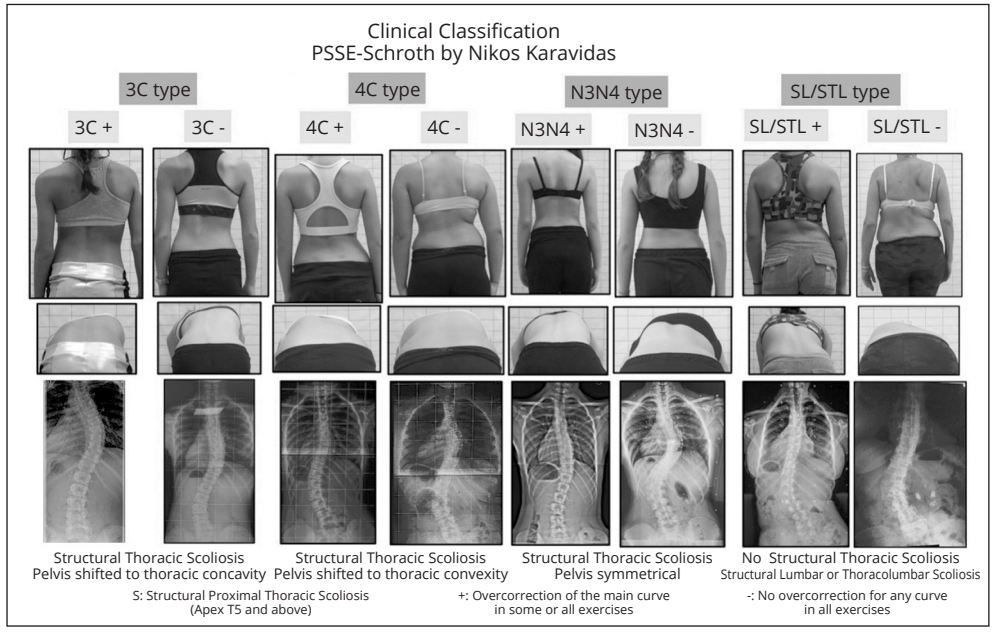

Figure 1.—PSSE-Schroth classification by Nikos Karavidas include eight different curve types.

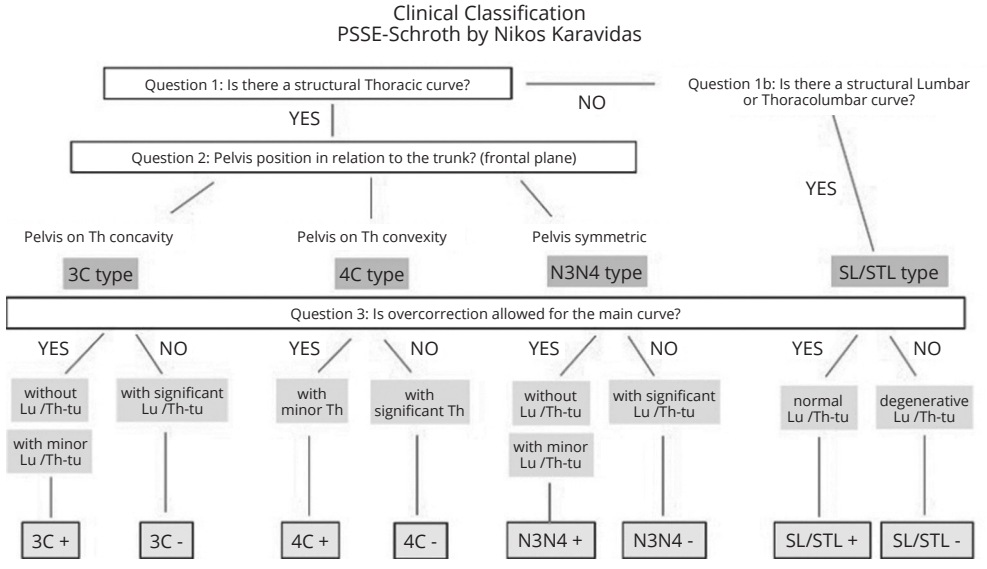

Figure 2.—Algorithm to classify curve types in PSSE-Schroth classification.

rection for the major curve when it is recommended and to avoid creating significant compensations when it is risky in balanced double curves.

The three-dimensional (3D) principles of correction are consisted of:

- 3D auto-correction;
- corrective / rotational breathing;
- muscle activation;
- stabilization.

3D auto-correction includes pelvic corrections, self-elongation, mobilizations by therapist, asymmetric sagittal straightening, and frontal plane corrections. Corrective/rotational breathing has the purpose to expand in 3D the collapsed areas during inhalation and to maintain the 3D correction and expansion during exhalation. Muscle activation is always in 3D corrective position, and the activation is increased during expiration using external aids or by special techniques like shoulder counter traction and thoracic counter traction (Figure 3, 4) and by mobilizations. When the exercise is finished, stabilization is re-

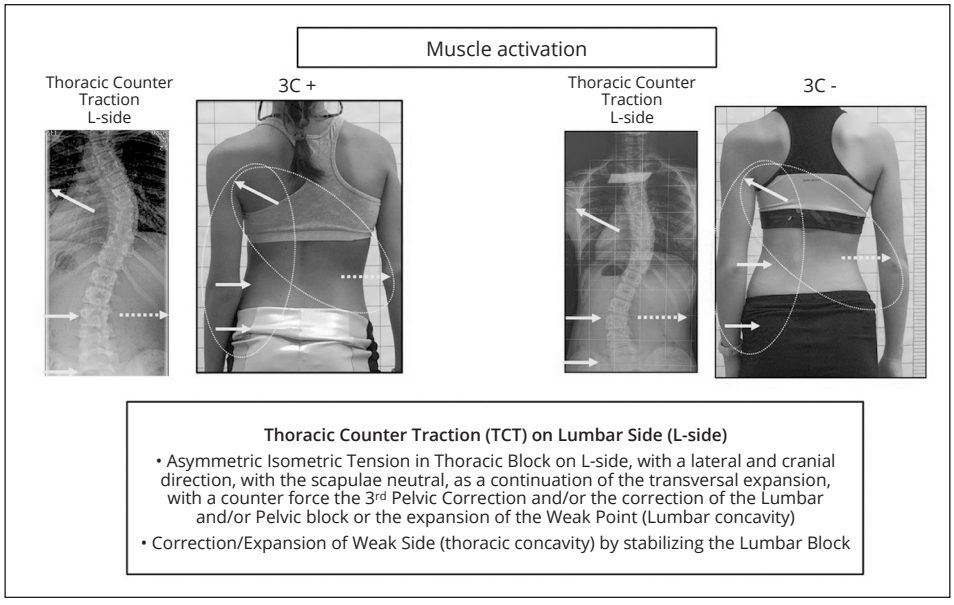

Figure 3.—Clinical and radiological representation of the corrective forces during thoracic counter traction.

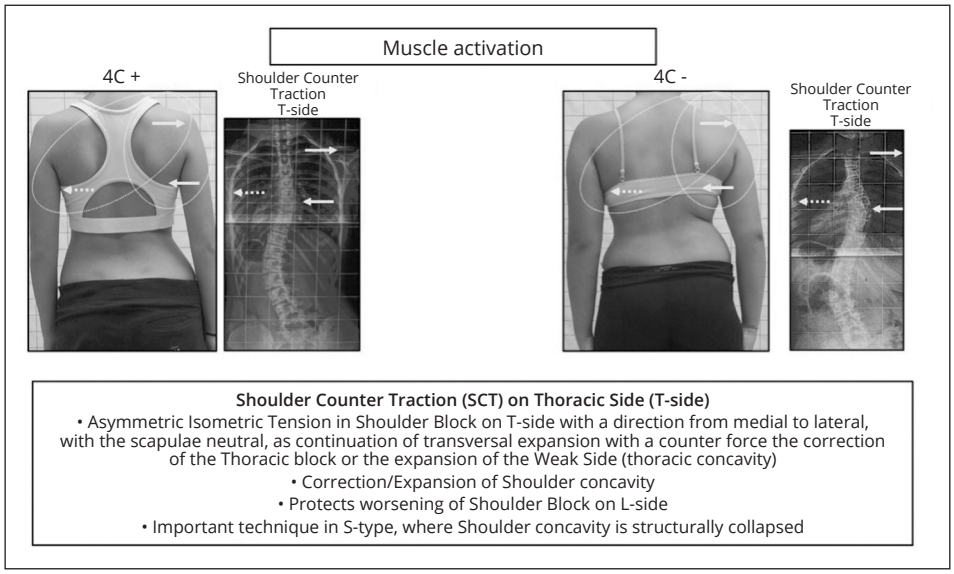

Figure 4.—Clinical and radiological representation of the corrective forces during shoulder counter traction.

quired for the implementation of the corrective posture into the activities of daily living.

PSSE-Schroth method differs from other Schroth-based approaches that have been described in the literature.[11] One of the main differences is the new classification that was introduced by PSSE-Schroth method. The concept of overcorrection with the classification of + or -, was introduced for the first time to define which curve types can get the maximum benefit of correction (overcorrection). Based on this different classification, the application of the exercises significantly differs from other Schroth-based approaches, having innovative concepts of corrective breathing, muscle activation, mobilizations combined with corrective breathing, new exercises, or different execution of already described Schroth exercises (Figure 5, 6).

Treatment protocol

According to the treatment protocol, patients had a recent X-ray at the beginning of treatment, not more than 2 months before coming to our clinic. Cobb angle was digitally estimated by Surgimap 2.3.2.1 software, by independent radiologists or medical doctors who were blinded to our research. A follow-up X-ray was prescribed in one

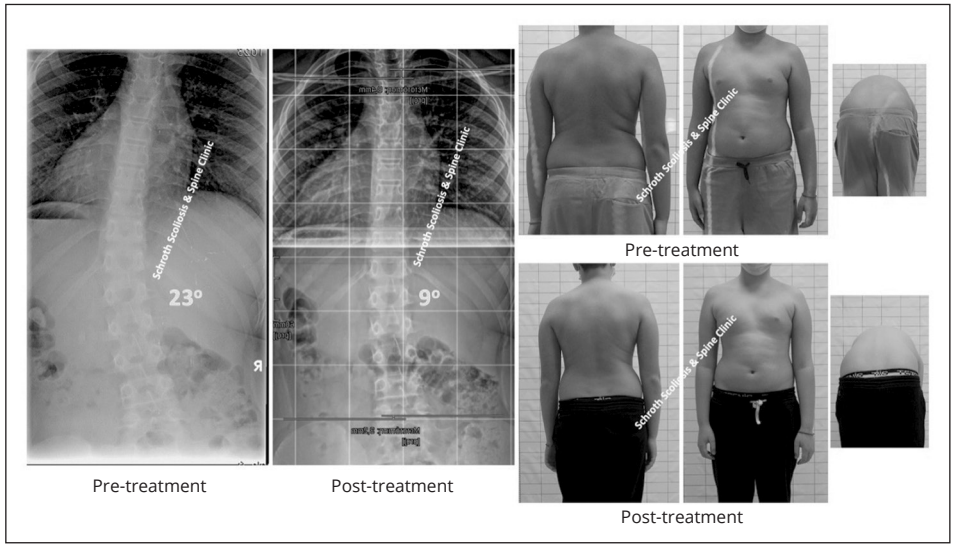

Figure 5.—Treatment result with PSSE-Schroth exercises.

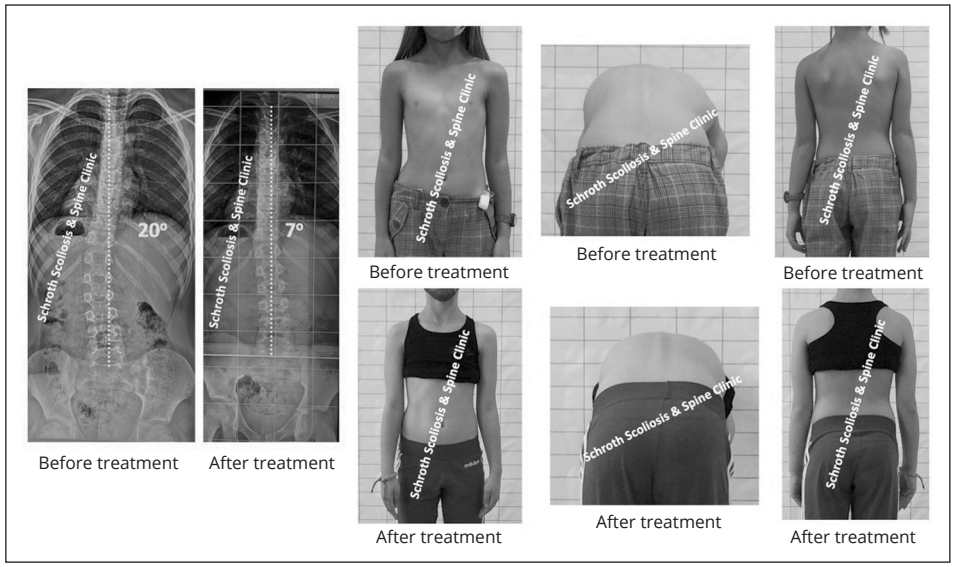

Figure 6.—Clinical and radiological improvement with PSSE-Schroth exercises.

year, except if the clinical measurements detected signs of progression, like an increase of ATR by scoliometer or more asymmetry on clinical photos.

Trunk Appearance Clinical Evaluation (TRACE) scale was used for body symmetry assessment, based on clinical photos.[15] Scoliometer and TRACE scale measurements were done every four to six weeks, by our physiotherapists, who were blinded to the research. As far as progression was suspected (2° or more difference in ATR), the patient was referred for x-ray earlier than one year and if the curve exceeded 25°, brace treatment was prescribed. In case that Cobb angle was still below 25°, but some progression was documented, we continued exercises with a more frequent clinical follow-up every two to four weeks.

The curve type classification was decided by the main author and the program of exercises was individualized according to curve type. For the experimental group, every patient was advised to perform exercises at home 5 times per week, for 30 minutes. Supervised sessions took place in our clinic once a week, for 55 minutes. The program of exercises was individualized according to curve type, based on PSSE-Schroth classification, and was videotaped during supervised sessions to ensure better performance at home. Curve-pattern specific recommendations for lying, sitting, and standing positions during activities of daily living were given to the patients, to emphasize the stabilization of the corrected posture.

Control group was consisted of patients that met our inclusion criteria at the time of first detection, excluding ATR >5° because this measurement could not be available, as it was not documented. All these patients had an initial diagnosis before coming to our clinic, they were not recommended to perform any PSSE exercises and their doctors suggested general or no exercises for at least 6 months and visited our clinic at a later stage, so they were matched with our subjects, having common baseline characteristics, and selected to serve as control group doing observation without therapeutic intervention (Table I). Their data were retrospectively collected from our prospective database, including all eligible subjects, to diminish selection bias.

TABLE I.—*Comparative data for PSSE-Schroth group and control group.*

Parameters	PSSE-Schroth group	Control group	P values
Total patients	163	58	N/A
Sex			
Female	148 (90.8%)	54 (93.1%)	0.3
Male	15 (9.2%)	4 (6.9%)	0.4
Mean age	12.6	13.1	0.8
Mean Risser	1.1 (0-2)	1.3 (0-2)	0.7
Risser 0	48 (29.4%)	9 (15.6%)	0.02*
Risser 1	58 (35.6%)	23 (39.7%)	0.3
Risser 2	57 (35%)	26 (44.8%)	0.05*
Girls pre-menarche	102 (62.6%)	30 (51.7%)	0.04*
Mean Cobb Th	20.8° (15°-25°)	19.4° (15°-25°)	0.7
Mean Cobb L/TL	20.7° (15°-25°)	19.2° (15°-25°)	0.8

N/A: not available.
*Statistically significant difference.

Compliance

Compliance was self-reported monthly, on a formal reporting sheet, by the patients and their families and was recorded in their digital medical file from the initiation to the end of follow-up. A scale from A to C was introduced to define adherence to treatment protocol. Group A had excellent compliance (five days per week or more), Group B had moderate compliance (three to four days per week) and Group C had poor compliance (less than two days per week).

Outcome parameters

Our main outcome parameters were radiological, evaluating the Cobb angle before and after intervention (improvement or progression was defined as difference more than 5°) and the number of patients that required a brace, at skeletal maturity (Risser 5). Success was considered as the stabilization or improvement of the scoliotic angle. Our secondary outcomes were related to quality of life and aesthetics; thus, we used SRS-22 questionnaire score with its 5 categories (function, pain, self-image, mental health, patient satisfaction), Trunk Appearance Perception Scale (TAPS) questionnaire, ATR by scoliometer and TRACE scale. SRS-22 and TAPS questionnaires were filled at the start of treatment and 1 year later.

Statistical analysis

We performed a power sample size calculation (95% confidence interval). This was based on previously published related literature,[4-6] determining the minimum sample for a sufficient statistical power (80%) for a moderate (0.50) to large (0.80) size effect and we estimated that in total 75 participants were needed.

Efficacy analysis was followed, excluding dropouts from statistical analysis, using paired *t*-test ($P<0.05$) with Statistical Package for Social Sciences (SPSS, Athens, Greece) 26.00 software. An additional requirement for inclusion into statistical analysis was to have at least one follow-up radiograph for comparison. However, we used also worst-case analysis, considering all dropouts as failures.

Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement was implemented to document methodological quality.[16]

Data availability

The data associated with this paper are available on reasonable request from the corresponding author.

Results

We recruited 179 subjects, but 16 (8.9%) were not included in efficacy analysis due to incomplete follow-up with a second X-ray. So, 163 patients (148 girls, 15 boys) were analyzed, having mean age 12.6 years (10.1 to 15.2), Risser sign 1.1 (0 to 2), Th Cobb angle 20.8° (15° to 25°) and L/TL Cobb angle 20.7°. (15° to 25°). Average ATR Th was 7.4° (5° to 11°) and ATR L/TL was 6.5° (5° to 12°). Eighty-five subjects (52.1%) had single curve and 78 (47.9%) had double curves. Mean follow-up time was 29.4 (12 to 56) months. The control group was consisted of 58 patients (54 girls, 4 boys; mean age 13.1 years, Risser sign 0-2, Th Cobb 19.4°, L/TL Cobb 19.2°), that were retrospectively analyzed and performed general or no exercises and did not significantly differ from intervention group (P=0.08).

Cobb angle change and brace prescription

For the PSSE - Schroth group, 103 patients (63.2%) remained stable, 39 (23.9%) improved and 21 (12.9%) worsened (Table II). Post-intervention Cobb Th was 20.3° (6° to 31°, 95% CI 0.34 to 1.96) and Cobb L/TL was 19.1° (8° to 29°, 95% CI 0.38 to 1.66). The mean difference reached statistical significance for Cobb L/TL (P=0.02), but not for Cobb Th (P=0.08) (Table III). Although 21 patients progressed, only 16 (9.8%) prescribed a brace, because some of the progressive subjects were still below 25° and there was no brace indication. In single curves the progression rate was 5.9% (five subjects), significantly lower (P=0.04) than in double curves was 20.5% (16 subjects).

The success rate (87.1%) was significantly higher compared to Control group (P=0.002), where 15 subjects (25.9%) were stable and 43 (74.1%) worsened. Similarly, the brace prescription was significantly less than Control group, where 39 subjects (67.2%) required brace treatment (P=0.003). In the worst-case analysis, considering all dropouts as fails, the rate for progression was raised to 20.7% and for brace prescription to 17.9%, remaining much lower in control group. Dropouts were defined as patients lost to follow-up, having no second x-ray for comparison.

TABLE III.—*Results pre and post treatment for Cobb angle.*

Parameter	Pre-treatment	Post-treatment	P value
Cobb, thoracic	20.8° (15°-25°)	20.3° (6°-31°) 95% CI: 0.34-1.96	0.08
Cobb, lumbar	20.7° (15°-25°)	19.1° (8°-29°) 95% CI: 0.38-1.66	0.02*

*Statistically significant difference.

Quality of life and body image

A significant decrease was observed for ATR Th with mean 5.9° (3° to 13°, P=0.04) and for ATR L/TL with mean 5.5° (3° to 11°, P=0.05) (Table IV). TRACE score markedly improved from 6.3 to 4.6 (P=0.04). SRS-22 questionnaire overall score pre-intervention was 83.2 (60 to 96) with subdomains pain 23.1 (19 to 25), mental health 18.1 (12 to 25), self-image 19.2 (11 to 23) and function 22.6 (18 to 25). A statistically significant improvement was observed post-intervention in overall score (90.3, 69 to 99, P=0.008), mental health (20.6, 15-25, P=0.005), self-image (21.4, 14 to 25, P=0.03). Improvement without statistical significance was obtained for pain (23.6, 20 to 25, p= 0.09) and function (23.1, 20 to 25, P=0.06), while the treatment satisfaction was excellent (9.1, 7 to 10). TAPS questionnaire score was 3.2 pre-exercises and 4.1 post-exercises (P=0.03).

Compliance

Overall compliance was good, having 78 subjects (47.9%) with excellent (A), 54 subjects (33.1%) with moderate (B) and 31 subjects (19%) with poor compliance (C). A subse-

TABLE IV.—*Results pre and post treatment for angle trunk rotation (ATR).*

Parameter	Pre-treatment	Post-treatment	P value
ATR, thoracic	7.4° (5°-11°)	5.9° (3°-13°)	0.04*
ATR, lumbar	6.5° (5°-12°)	5.5° (3°-11°)	0.05*

*Statistically significant difference.

TABLE II.—*Results pre- and post-treatment for curve progression.*

Parameter	Group	Stable	Improved	Progressed	Success rate	P value
PSSE-Schroth group	163	103 (63.2%)	39 (23.9%)	21 (12.9%)	87.1%	0.002
Control group	58	15 (25.9%)	0 (0%)	43 (74.1%)	25.9%	

quent analysis for the fully compliant (A) showed a success rate of 94.8%, as 42 (53.8%) remained stable, 32 (41%) improved and four (7.7%) progressed, significantly higher than poorly compliant in group C (P=0.002), where 20 (64.5%) remained stable 0 (0%) improved and 11 (35.5%) progressed, and moderately compliant in group B (P=0.05) where 41 remained stable (75.9%), seven improved (13%) and six progressed (11.1%). The number of patients needed a brace was significantly lower (P=0.01) in group A (four subjects, 5.1%) compared to group C (eight subjects, 25.8%), but not with group B (four subjects, 7.4%, P=0.09).

Discussion

PSSE-Schroth exercises can effectively treat AIS patients at early growth, significantly reducing the risk of progression and brace wearing. Only 12.9% of our sample had progression >5° and 9.8% required brace treatment. The results were significantly in favor of PSSE-Schroth group, compared to control group that followed general, non-specific or no exercises. Moreover, all quality of life and body image measurements were significantly improved after intervention (ATR, TRACE, SRS-22, and TAPS scores). Although the ATR decrease achieved statistical significance, the difference was not enough to provide significant clinical benefit for the patient.

Besides the statistical significance, we must pinpoint the clinical significance of our results, because a main goal of treatment from patient's perspective is to avoid bracing. Even in the progressive cases, the delay of brace indication and the reduction of brace treatment duration may be considered as useful for them.

Compliance seems to be a key factor for success, as the fully compliant had significantly less progression rate and brace prescription. The overall good compliance in our sample can be attributed to the clearly described treatment protocol and to the regular supervised sessions and clinical follow-up, which provided to our patients the necessary information to increase their motivation.

Comparability with previous studies

Our results are comparable with similar published literature. Negrini *et al*.[4] recruited 74 subjects, including two group of patients, Risser 0-1 with Cobb angle >15° and ATR >7°, and Risser 2-3 with Cobb angle >20° independent of ATR. SEAS exercises were applied. Clinical re-evaluation occurred every 6 months and radiological in one year. Supervised sessions took place every 2-3 months, and the patients followed a daily home-program of 5 minutes and twice per week 40 minutes with a local physiotherapist. Brace prescription (6.1%) and progression (11.8%) rates were very similar to our results (9.8% and 12.9% respectively).

Monticone *et al*.[5] performed task-oriented and self-correction exercises in an RCT, including curves 10°-25° at Risser 0-2, age >10 years. Sixty-nine percent of the exercise group improved, 23% remained stable and only 8% worsened. However, the authors used a cut-off point of 3° to define progression or improvement, which can probably explain the high rate of improvement compared to our study. An advantage of this study was the long follow-up of approximately 42.7 months. Zapata *et al*.[6] used BSPTS exercises with a small sample of AIS patients with Cobb angle 12°-20° at Risser 0. Progression rate was 16% and brace prescription 37%, significantly more than our study. This difference can be explained by the intensity of treatment, as the patients were asked to perform exercises only 3 days per week for 15 minutes, and compliance was not reported. All improved cases were single curves, which is compatible with our findings.

Strengths and limitations of the study

Our study had many strengths in comparison to previously published studies. We used the largest sample in the literature (221 subjects, 163 for exercise group and 58 for control group), at a high risk or progression. Our treatment protocol was clearly defined and standardized in advance, and we used clinical assessment every 4 to 6 weeks, by blinded therapists, to detect signs of progression and to refer patient for bracing, so we had no worsening more than 8°. No previous study implemented this specific assessment protocol, by standardized repetitive clinical measurements of trunk rotation and body symmetry to detect progression, which is an advancement of PSSE-Schroth method, utilizing a unique patient evaluation form. Early detection of progression is an important role of specialized physiotherapists and crucial when PSSE is exclusive treatment. We also emphasized in the ADL training, to decrease the asymmetrical loading and the potential for progression. Efforts were made to eliminate all potential bias and confounding variables.

A main limitation of our study was the lack of randomization, but it was impossible, because all our patients were advised to follow exercises after visiting our clinic for consultation. Therefore, our control group was retrospectively analyzed, and the number of progressed cases was overestimated, because some patients that did not experience progression might have no reason to visit our clinic. So, it is unsure whether the control group is truly

representative of general scoliotic population following non-specific or no exercises. Another limitation could be the use of Risser sign for determination of growth stage, which is not as accurate as Sanders scale, so part of our patients might had not reached full skeletal maturity at the time of statistical analysis. We chose Risser sign to make it comparable with the control group, because Sanders scale could not be applicable for retrospective analysis, due to lack of hand X-rays at the time of initial diagnosis. However, in some borderline patients Sanders scale was implemented to take treatment decisions.

Conclusions

In conclusion, PSSE-Schroth method was effective in AIS treatment around the riskiest period for progression at early growth. Our approach improved trunk rotation, self-perception, and quality of life. The clinical significance of our study based on the reduced rate of brace prescription, which is one of the main goals of treatment for mild scoliosis. Our study adds scientific evidence to the existed literature, supporting the superiority of PSSE compared to general or non-specific exercises.

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Conflicts of interest

Nikos Karavidas is the inventor of PSSE-Schroth method. All other authors have no conflict of interest.

Authors' contributions

Nikos Karavidas contributed to study conception, material preparation, data collection and analysis. Patient evaluation and curve type classification was made by Nikos Karavidas. First draft was written by Nikos Karavidas. Paris Iakovidis, Ioanna Chatziprodromidou, Dimitrios Lytras, Konstantinos Kasimis, Athanasios Kyrkousis, and Thomas Apostolou made the final approval of the manuscript and contributed to study conception and design.

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