Musculoskeletal Science and Practice 72 (2024) 102952

Contents lists available at ScienceDirect

Musculoskeletal Science and Practice

journal homepage: www.elsevier.com/locate/msksp

Original article

Comparison of the efficacy of Schroth and Lyon exercise treatment techniques in adolescent idiopathic scoliosis: A randomized controlled, assessor and statistician blinded study

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ARTICLE INFO

Keywords:
Adolescent idiopathic scoliosis
Scoliosis severity
Quality of life
Schroth
Lyon
Conservative treatment

ABSTRACT

Background: Adolescent idiopathic scoliosis (AIS) is the most common vertebral disorder in adolescence.
Objectives: The purpose of this study was to compare the effectiveness of Schroth and Lyon exercise methods on Cobb angle (CA), angle of trunk rotation (ATR), quality of life (QoL), and perceived trunk appearance in patients with AIS.
Methods: The 31 participants diagnosed (diagnosis age = 12.2 ± 0.9) with AIS by a physician following the Lenke criteria and subsequently referred to the outpatient clinic were enrolled in the study. All participants were randomly assigned between the Schroth group (SG) and Lyon group (LG) for 6 months of supervised and home treatment. The participants' CA, ATR, Scoliosis Research Society-22 (SRS-22), and Walter-Reed Visual Assessment Scale (WRVAS) were assessed as a baseline, and again following the treatment by the same researcher who remained blinded to the study.
Results: In 2-way mixed-design repeated-measures ANOVA analysis, when the change in time was analyzed between the groups (Group × Time [interaction]), a statistical difference was found more significant in SG for the CA-thoracic ($F = 103.1$, $p < .01$, 95% CI = 4.1; 2.0 to 6.2), CA-lumbar ($F = 19.1$, $p < .01$, 95% CI = 1.7; 1.0 to 2.4), ATR ($F = 64.1$, $p < .01$, 95% CI = 1.7; 1.2 to 2.3), and WRVAS ($F = 169.5$, $p < .01$, 95% CI = 6.5; 3.2 to 9.9) parameters. The LG was only more significantly improved in the SRS-22 total score ($F = 15.7$, $p < .01$, 95% CI = −0.9; −0.2 to −1.6).
Conclusion: In the study, The Schroth exercises gave more favorable results than Lyon exercises in terms of CA-T, CA-L, ATR and WRVAS in the conservative treatment of AIS, while Lyon exercises gave more favorable results in terms of QoL. Additionally, according to the results of this study, it was found that the QoL of participants in SG decreased after treatment compared to baseline.

1. Introduction

Adolescent Idiopathic Scoliosis (AIS) is defined as three-dimensional torsional disorder characterized by lateral deviation of the spine greater than 10°, vertebral rotation, and reduced normal thoracic kyphosis (Negrini et al., 2011; Grivas et al., 2006). AIS is the most common type of scoliosis, which commonly begins in early puberty, and affects 1–4% of adolescents, whilst being more common in 10–18-year-old females (Cheng et al., 2015).

To manage the disorder from progressing, various treatment approaches have been proposed for AIS, including exercise, surgery, traction, bracing, casting, biofeedback, and simple observation. Factors such as the patient's age, age at diagnosis, progression and severity of the curvature should also be taken into consideration in the treatment and management of this disorder (Hawes and O'brien, 2006; Weiss et al., 2006; Janicki and Alman, 2007). Various exercise techniques are used in the treatment of scoliosis, including the Schroth method, Lyon method, scientific exercise approach to scoliosis method, Dobomed

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https://doi.org/10.1016/j.msksp.2024.102952
Received 11 August 2023; Received in revised form 1 April 2024; Accepted 3 April 2024
Available online 12 April 2024

method, Side-Shift method, Functional Independent Treatment for Scoliosis method, core stabilization exercises, and Pilates, among others (Negrini et al., 2011; Lehnert-Schroth, 1992; Gür et al., 2017).

The Schroth method is a physiotherapeutic approach that uses isometrics and other exercises to strengthen or lengthen the asymmetrical muscles. The treatment program consists of scoliotic posture correction and a breathing pattern with the help of proprioceptive and exteroceptive stimulations and mirror control (Hawes and O'brien, 2006; Lehnert-Schroth, 1992). In our previous study, we showed that the Schroth exercises had a considerable effect on patients' CA, thoracic angle of trunk rotation (ATR), cosmetic aspect of trunk disorder, spinal mobility, and quality of life (QoL) (Kocaman et al., 2021). In a study comparing Schroth and Pilates exercises, Kim et al. reported that Schroth exercises can significantly reduce the CA compared to Pilates exercises and can improve the load distribution in the lower extremities (Kim and HwangBo, 2016). As a conservative treatment method for AIS, the Schroth method, which is planned specifically for the patient's curvature type and degree, is thought to be an effective approach (Schreiber et al., 2015; Park et al., 2017).

The Lyon method (Lehnert-Schroth, 1992; Stępień et al., 2017) and that of "Mezieres" were introduced in France during the 1960s (Lehnert-Schroth, 1992; Stępień et al., 2017; Negrini and Marchini, 2007a; Negrini et al., 2008). The Lyon method is a combination approach that includes three dimensional mobilization of the spine, mobilization of the ilio-lumbar angle for lumbar scoliosis, patient education, and activities of daily living, including correction of the sitting position (Berdishevsky et al., 2016). According to the information we obtained in the review studies of Negrini (Negrini et al., 2008) and Bialek (Białek, 2011), two studies examining the effectiveness of Lyon exercises in participants with AIS were reported by Mollon (1986) (Mollon and Rodot, 1986) and Duconge 2002 (Ducongè, 2002). However, the full texts of these two studies could not be accessed. Additionally, the methodological quality of the studies is controversial. In general, the more recent studies on the Lyon concept have mostly focused on brace treatment. (Aulisa et al., 2014, 2015; de Mauroy et al., 2008).

According to Scientific Society on Scoliosis Orthopaedic Rehabilitation and Treatment (SOSORT), the number of studies and evidence investigating the effects of conservative treatment of AIS is scarce (Negrini et al., 2011). In addition, it is not yet known which of the Lyon, Scientific Exercise Approach to Scoliosis (SEAS), Schroth, Barcelona Scoliosis Physical Therapy School approach (BSPTS), Dobomed approach, Side Shift approach and Functional Individual Therapy of Scoliosis approach (FITS) designed specifically for scoliosis in the literature is more effective in patients with adolescent idiopathic scoliosis (Bettany Saltikov et al., 2014a). Given the significance of conservative treatment for AIS, this study aimed to compare the effectiveness of the 6-month Schroth and Lyon methods, both considered important conservative treatment approaches for moderate AIS, without the use of a brace.

2. Materials and method

2.1. Study design

The research was designed as a randomized-controlled, assessor and statistican blinded study, which was conducted in the outpatient clinic of Kırşehir Ahi Evran University School of Physical Therapy and Rehabilitation between May 2021 and September 2022. Written informed consent was obtained from each participant prior to the study's commencement. The study protocol was approved by the local ethics committee (April 27, 2021), and was conducted in accordance with the principles of the Declaration of Helsinki. The study was registered under code NCT05223972 on the "ClinicalTrials.gov" website.

2.2. Participants

Individuals who were diagnosed with AIS by a physician in the hospital setting according to the Lenke (Slattery and Verma, 2018) criteria and subsequently referred to the outpatient clinic were randomly included in the study. Cobb angle measurements were evaluated by the same physician immediately pre and post-treatment. The inclusion criteria were: 1) aged between 10 and 18 years old; 2) first time diagnosed with AIS; 3) Risser sign of 0–3 and CA of 10–30°; 4) Sander's classification of 0–6 (RISSER, 1958); 5) Lenke curve Type 1 or Type 1A (de Mauroy et al., 2008); and, 6) volunteered to participate in the study. Individuals with other types of scoliosis, those with a history of spinal surgery, using brace, exercise contraindications, previously treated for AIS, rheumatological disease and/or other neuromuscular problems were excluded from the study. The patients included in the current study were not allowed to make any lifestyle changes that could negatively affect their curve and/or general health status during the study. After each exercise session, both the patients and parents were asked by the researcher whether they had compliance to this situation.

2.3. Interventions

For both the Schroth group (SG) and Lyon group (LG), supervised exercise training sessions (duration: 90 min each) were administered three times per week for a total of 6 months. The participants in both groups were given traditional exercises as a home program. All home exercises were controlled at each treatment session. These home exercises consisted of stretching exercises (particularly for the muscles on the concave side of the curve), posture training, breathing exercises, and spinal flexibility exercises. The exercise program gradually increased in intensity in accordance with each participant's functional improvement. All interventions applied to the patients in both groups were demonstrated and supervised by the same therapist (experience>10 years) who had both Schroth and Lyon certificate. The exercise compliance of the included participants in the study was monitored using a logbook. Weekly, the parents/patient and therapist were recorded exercise compliance with signatures. If the patient's compliance with exercise was below 70%, precautions were taken (Schreiber et al., 2014; Friedrich et al., 1998).

2.3.1. Schroth group

Schroth exercises consist of passive and active postural autocorrection exercises based on kinesthetic and sensorimotor principles that are undertaken repeatedly. The ultimate goal of the Schroth method is to enable the patient to consciously maintain a correct posture during their daily living activities (Lehnert-Schroth, 1992). This requires the repetition of corrective movements that are performed with the aim to improve postural motor control. Schroth exercises also include strength and endurance training of postural muscles so as to improve the curve, raise the patient's self-image, and to reduce their level of physical pain (Brink et al., 2017). In the current study, the applied Schroth exercises progressed from greater to lesser passive support, from more to less feedback, and from a lying position to sitting or standing, in accordance with the patient's ability to perform each specific exercise (Schreiber et al., 2015).

Patients were placed in an asymmetric position in order to maximize correction in trunk symmetry. The Schroth program includes exercises for rotational breathing, spinal elongation, de-flexion, stretching, derotation, and also strengthening. Each exercise is aimed to improve the curvature, muscle strength, and endurance of the patients' postural muscles. During the Schroth exercises, rice bags, foam blocks, a sitting stool, and long sticks are used to adjust the posture of the patient and for the provision of passive support. In the study, the intensity of the Schroth exercises was gradually increased according to each patient's improvement in exercise performance by decreasing the amount or degree of passive support, changing the patient's position, and adjusting

the sets and repetitions of the exercises. Each exercise comprises multiple sets and repetitions of isometric corrective contractions synchronized with proper breathing techniques. Throughout the treatment process, the exercises progressively increase in difficulty, transitioning from static to dynamic movements and from lying down to sitting and eventually to standing positions. As a participant's performance improves, the prescribed dosage escalates from the initial to the target intensity. Initial exercise intensities typically involve 3–5 sets and 4–6 repetitions, while target intensities range between 3–5 sets and 6–10 repetitions. These intensity levels adhere to the recommendations provided in the Schroth Therapists' Exercise Manual (Hennes, 2011). The same exercises were also applied to patients as a home program. The exercise program showed in Table 1.

2.3.2. Lyon group

The Lyon set of exercises include the correction of lumbar lordosis and thoracic kyphosis, anterior plane correction, segmental mobilization, core stabilization, proprioception, balance, and stabilization exercises (Berdishevsky et al., 2016). The training program included exercises targeting posture control, strengthening, balance, and were performed to improve the patients' postural balance by highlighting defects, learning correction, and integration in their daily life activities. The participants were instructed to control their breathing using the expiratory reserve volume as the pelvis was fully stabilized. Also emphasized were 3D mobilization of the spine, mobilization of the iliolumbar angle (lumbar scoliosis), therapeutic patient education, sitting position, and the endurance of the deep paraspinal muscles (Bettany Saltikov et al., 2014b). The same exercises were also applied to patients as a home program. Throughout the treatment duration, the exercises applied to the Lyon group were progressively intensified, similar to those in the SG. As the patient's performance and adaptation to the exercises improved, the exercise dosage was increased. This increase shifted from the initial 3–5 sets and 4–6 repetitions to the target range of 3–5 sets and 6–10 repetitions. The intensity levels of these exercises have been designed in accordance with the recommendations given in the Lyon Exercise Manual (De Mauroy, 2012). The Lyon exercises are shown in Table 2.

2.4. Outcome measures

Sociodemographic data, body mass index (BMI), sex, and detailed medical history were recorded as the baseline for each participant patient during a face-to-face interview.

2.4.1. Primary outcome

1. Cobb angle

Table 1
Schroth exercises programme.

Beginner Phase	Intermediate Phase	Advanced Phase
3D corrective breathing	3D corrective breathing	3D corrective breathing
Shoulder counter-traction in supine position	Shoulder counter-traction in sitting position	Shoulder counter-traction in sitting position
Shoulder counter-traction in prone position	Chest twister	Chest twister
Shoulder counter-traction in side-lying position	Muscle cylinder in sitting position	Muscle cylinder in kneeling position
Muscle cylinder in supine position	Big bow	Big bow
Muscle cylinder in side-lying position	Shoulder counter-traction between two poles	Shoulder counter-traction between two poles
Muscle cylinder in sitting position	Schroth gait	Schroth gait
Chest twister	Removing the stool	Removing the stool

Table 2
Lyon exercise programme.

Beginner Phase	Intermediate Phase	Advanced Phase
Visual and vestibular corrections	Visual and vestibular corrections	Visual and vestibular corrections
Kyphotisation	Serratus anterior exercise	Serratus anterior exercise
Passive thoracic mobilization	Simple Thoracic Shift	Active corrective bending
Passive segmental rib-vertebral mobilization	Thoracic Shift- Derotation in sitting or standing position	Self active axial elongation with plastic rubber
Simple Thoracic Shift	Self Active axial elongation	Grand Porter exercise
Stabilization of spine on prone position	Mobilization of iliolumbar angle (lumbar curve)	Mobilization of iliolumbar angle (lumbar curve)
Mobilization of iliolumbar angle (lumbar curve)	Stabilization of spine on prone position on sidelying	Balance exercises in front of mirror
Core stabilization on swiss ball	Active - segmental rib mobilization	Stabilization of spine on swiss ball

The curve magnitude of each patient's spine was evaluated using the Cobb method, which is considered the gold standard for monitoring scoliosis progression. CA were measured, in degrees, using a standard anteroposterior standing full spine radiograph (Pruijs et al., 1994).

2.4.2. Secondary outcomes

1. Angle of trunk rotation

ATR was evaluated using Bunnell's scoliometer and Adam's forward bend test. The patients were asked to bend forward, and the ATR (between the horizontal plane and a plane across the posterior aspect of the trunk) was measured on the apical vertebrae of the curve. For clinical significance, the change in ATR must be $> 4^{\circ}$. This measurement form has been proven to be sensitive, specific, and reliable (Amendt et al., 1990).

2. Quality of life:

The Scoliosis Research Society-22 (SRS-22) questionnaire, which is a validated self-reporting instrument, was used to assess the participants' health-related QoL. The questionnaire consists of five domains: self-image, function, pain, mental health (five questions each), and satisfaction with treatment (two questions). The questionnaire has a total of 22 items that are scored from 1 (*worst*) to 5 (*best*). The final score is the average of all five domains. The instrument has been reported to have good validity and test-retest reliability (Asher et al., 2003).

3. Perceived Trunk Appearance

The patients' perceived trunk appearance was evaluated according to the Walter Reed Visual Assessment Scale (WRVAS), which was designed for the assessment of perceived physical disorder of patients with idiopathic scoliosis. The test allows patients to describe their perception of their disorder according to seven visible spinal aspects including shoulder level, body curve, head-pelvis, flank prominence, rib prominence, scapular rotation, and head-rib-pelvis. Scores for each category range from 1 (*no disorder*) to 5 (*worst disorder*), and the total score is the sum of the scores from the seven domains (Sanders et al., 2003). The WRVAS was found to have high reliability and validity for AIS patients to assess their perception of disorder (Colak et al., 2020).

2.5. Sample size

To determine the sample of the study, the G × Power program, version 3.1.9.4 (Heinrich Heine University, Düsseldorf, Germany) was

used (Faul et al., 2007). According to previous studies, the effects of exercises on the CA of the main curve were determined to be from small to moderate (Cohen's d: 0.16–0.38) (Białek, 2011; Kuru et al., 2016). In order to obtain 80% statistical power (1 - β error probability) with an α error level probability of 0.05 and an anticipated correlation of r = 0.11 between repeated measurements over time. We performed repeated measure analysis of variance (ANOVA) with time and between factor interaction, to detect a medium effect size of 0.30 to for the interaction. Using two measurements for the primary outcome, the program generated a sample size of 26. Considering the anticipated 15% dropout rate and aiming to increase the statistical power of the results, a total of 31 participants were recruited to the study.

2.6. Randomization and blinding

A randomization process was performed for the 31 individuals with AIS. The participants were randomly divided into two groups as SG and LG using stratified randomization based on their CA, age, and gender. These strata were formed in terms of age, gender and cobb angle. Since the patients who met the inclusion criteria for the study were selected from 10 to 18 years of age and 10–30 Cobb angles, our strata were 10–14 or 15–18 for age; CA, 10–20 or 21–30 for cobb angle were determined. Stratified randomization was performed with numbers sorted using the Research Randomizer program on the "www.randomizer.org" website (Laita et al., 2018). All baseline (month 0) and post-treatment assessments (month 6) were conducted by the same researcher, who remained blinded to the group allocations throughout the study. The patients included in the study were distributed into groups based on the random number table obtained from the "randomizer.org". Also post treatment assessment were made immediately after the treatment.

2.7. Statistical analysis

The statistical analysis of the study was performed using IBM's SPSS software (version 24). The conformity of the variables to the normal distribution was examined using both visual (histogram and probability graphs) and analytical (Shapiro-Wilk) testing methods. Descriptive analyses examined the mean and standard deviation for normally distributed variables. Number and percentage were given for nominal variables. Two-way analysis of variance (Mixed-design repeated measures ANOVA) was used to evaluate the main effect of groups (SG vs LG), time (Baseline vs post-treatment) and the group by time interactions for each outcome. All outcome analyses were conducted according to the intention-to-treat principle. For statistical significance, the total Type-1 error level was set as 5%.

3. Results

Overall, 82 individual patients with scoliosis were admitted to the department, and of those, 31 (24 females, 7 males) met the inclusion criteria of the study. The patients were randomized as $n = 15$ for the SG and $n = 16$ for the LG. The study was completed with 100% attendance compliance. The flowchart of the study is presented in Fig. 1.

The baseline, post-treatment and score changes for the CA-Thoracic (CA-T), CA-Lumbar (CA-L), ATR, SRS-22, Risser Sign and WRVAS parameters of the groups are presented in Table 3.

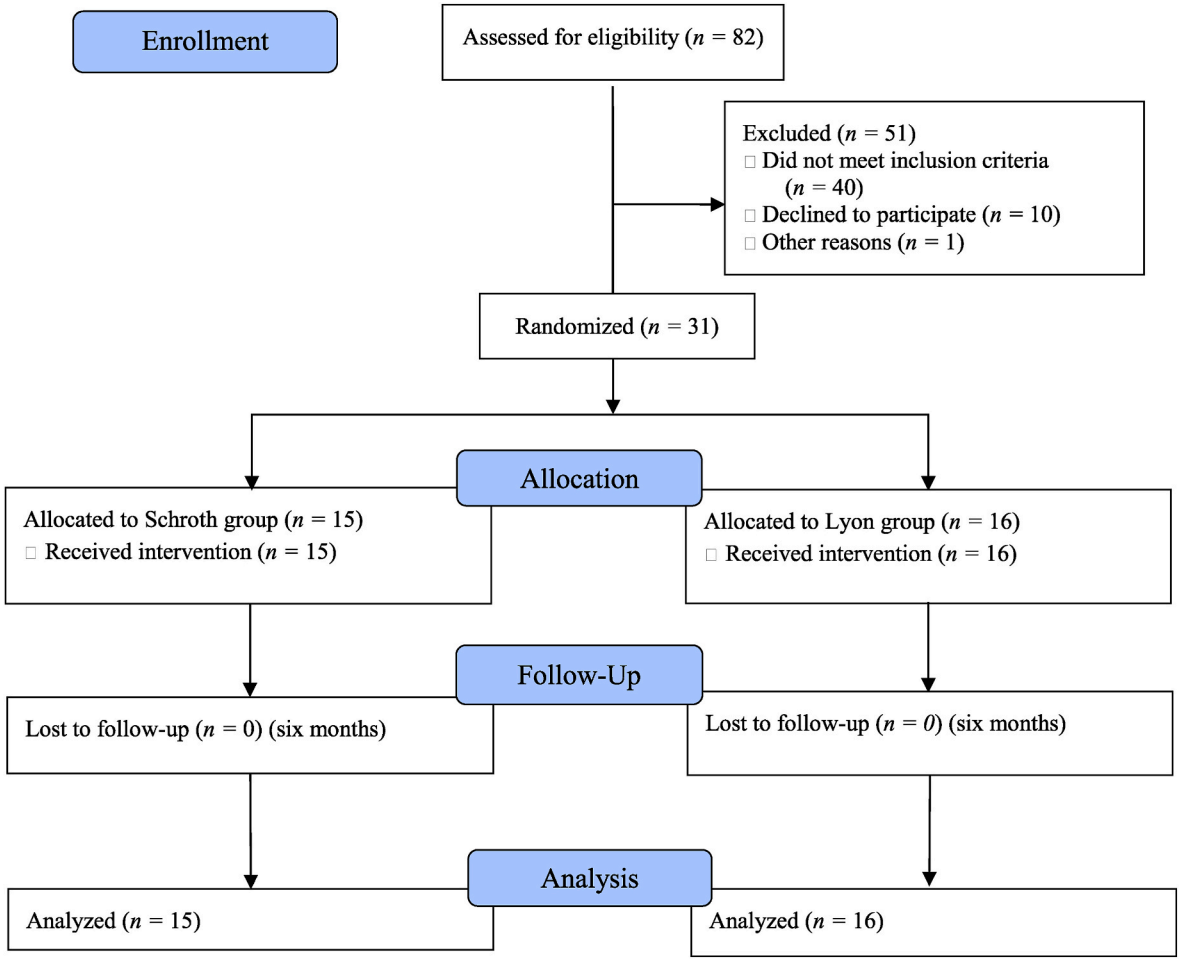

Fig. 1. Flowchart of the study.

Table 3
Demographic, physical, and clinical characteristics of the groups.

		SG ($n = 15$)		LG ($n = 16$)	
		X	SD	X	SD
Age (years)		14.0	1.9	14.2	2.0
BMI (kg/m^2)		22.2	2.7	21.8	2.7
		n	**(%)**	***N***	**(%)**
Risser Sign	0	2	13.3	2	12.5
	1	3	20.0	3	18.8
	2	6	40.0	6	37.5
	3	4	26.7	5	31.2
Sex	Female	12	81.2	12	76.5
	Male	3	18.7	4	23.5
Curve type	Right Thoracic (Lenke Type 1)	7	46.6	6	37.5
	Right Thoracic-Left lumbar (Lenke Type 1A)	8	53.3	10	62.5

SG: Schroth Group, LG: Lyon Group, BMI: Body Mass Index, *X*: Mean, *SD*: Standard Deviation.

There were statistically significant main effect of time for CA-T ($p < 0.001$) and CA-L ($p < 0.001$). The 2-way mixed-design repeated-measures ANOVA of the CA-T ($F = 103.1$, $p < 0.001$) and CA-L ($F = 19.1$, $p < 0.001$) indicated a significant group × time interaction. Individuals in the SG demonstrated greater improvement in CA-T and CA-L than those in the LG. In addition, a comparison of change scores between the SG and LG demonstrated a between-group difference of 4.1 (°) (95% CI: 2.0.-6.2) on the CA-T and a between-group difference of 1.7 (°) (95% CI: 1.0–2.4) on the CA-L (Table 4).

There were statistically significant main effect of time for SRS-22 total score ($p < 0.001$). The 2-way mixed-design repeated-measures ANOVA of SRS-22 total scores ($F = 15.7$, $p < 0.001$) indicated a significant group × time interaction. Individuals in the LG experienced greater improvement in SRS-22 and those in the SG experienced a significant reduction in QOL scores. The comparison of change scores between the SG and LG revealed a significant between-group difference of −0.9 (95% CI: −0.2 to −1.6) on the SRS (Table 4).

There were statistically significant main effect of time for ATR ($p < 0.001$). The 2-way mixed-design repeated-measures ANOVA of ATR ($F = 64.1$, $p < 0.001$) showed a significant group × time interaction. Individuals in the SG experienced greater improvement in ATR degree scores than those in the LG. The comparison of change scores between the SG and LG demonstrated a between-group difference of 1.7 (95% CI: 1.2–2.3) on the ATR scores (Table 4).

There were statistically significant main effect of time for WRVAS ($p < 0.001$). The 2-way mixed-design repeated-measures ANOVA of WRVAS ($F = 169.5$, $p < 0.001$) indicated a significant group × time interaction. Individuals in the SG experienced greater improvement in WRVAS scores than those in the LG. The comparison of change scores between the SG and LG revealed a between-group difference of 6.5 (95% CI: 3.2–9.9) on the WRVAS (Table 4).

Similarly, when the changes within the groups (within group [Time-Main effect]) were analyzed, a statistical difference was found for all parameters the CA-T ($F = 333.2$, $p < 0.001$), CA-L ($F = 33.8$, $p < 0.001$), ATR ($F = 222.2$, $p < 0.001$), and WRVAS ($F = 124.6$, $p < 0.001$), SRS-22 total score ($F = 15.7$, $p < 0.001$).

Additionally, CA changes of the participants included in the study were evaluated according to SOSORT criteria (Negrini et al., 2016). According to this criterion; The participants are divided into improved (CA>6° or more), unchanged (CA = ±5°) and progressed (CA>6° or more). The changes in the participants in the groups were as follows: In SG 10 participants improved, 5 participants unchanged; in LG 4 participants improved, 7 participants unchanged and 5 participants were progressed.

All individuals in both SG and LG participated in all therapy sessions during the study. In addition, the home exercise completion rate of all individuals included in the study was 100%.

4. Discussion

To the best of our knowledge, there are no studies in the literature that have previously compared the effectiveness of the Schroth and Lyon methods of exercise. According to the current study's findings, the Schroth exercises treatment was found to have a significant favorable impact on the CA-T, CA-L, WRVAS and ATR parameters when compared to the Lyon exercises. However, in terms of SRS-22 the LG were revealed to have experienced a more significant change following the period of treatment. It was determined that there were significant changes in the CA-T, CA-L, perceived trunk appearance and ATR scores of individuals in both groups after the treatment compared to baseline. The QoL of participants in the LG changed positively, but the QoL of participants in the SG was negatively affected.

According to the current study's results, improvements were detected in the CA-T, CA-L and ATR values of all participants. However,

Table 4
Baseline, post-treatment and change values for Cobb, ATR, SRS-22, and WRVAS parameters.

		SG ($n = 15$)		LG ($n = 16$)		Main Effect (Time)	Main Effect (Group)	Group × Time (Interaction)	Pairwise Comparison		Between Group Differences in Change Scores
		X	*SD*	*X*	*SD*	*p1*	*p2*	*F/p value*	SG (Mean Difference ±SD/p)	LG (Mean Difference ±SD/p)	Mean (95% CI)
CA-T (°)	Baseline	22.8	3.1	20.4	2.2	**<0.001**	**<0.001**	103.1/**<0.001**	6.3 ± 0.4/	2.3 ± 0.2/	4.1 (2.0, 6.2)
	Post-treatment	16.4	2.7	18.1	2.4				**<0.05**	**<0.05**	
CA-L (°)	Baseline	18.3	3.7	17.1	1.9	**<0.001**	**<0.05**	19.1/<**0.001**	4.1 ± 0.9/	2.4 ± 0.03/	1.7 (1.0, 2.4)
	Post-treatment	14.1	2.8	13.8	1.4				<**0.05**	<**0.05**	
SRS-22 (score/ total score)	Baseline	4.2/5	0.3	4.1/5	0.4	**<0.001**	**<0.05**	15.7/**<0.001**	−0.7 ± 0.01/	0.2 ± 0.4/	−0.9 (−0.2, −1.6)
	Post-treatment	3.5/5	0.3	4.3/5	0.9				**<0.05**	**<0.05**	
ATR (°)	Baseline	4.8	1.2	4.5	1.3	**<0.001**	**<0.001**	64.6/**<0.001**	2.6 ± 0.3/	0.8 ± 0.1/	1.7 (1.2, 2.3)
	Post-treatment	2.2	0.9	3.7	1.4				**<0.05**	**<0.05**	
WRVAS (score/ total score)	Baseline	16.0/ 35	1.8	11.5/ 35	2.6	**<0.001**	**<0.001**	169.5/**<0.001**	7.5 ± 0.1/	1.0 ± 0.4/	6.5 (3.2, 9.9)
	Post-treatment	8.6/ 35	1.8	10.5/ 35	2.2				**<0.05**	**<0.05**	

CA-T: Cobb angle- Thoracic, CA-L: Cobb angle- Lumbal, SRS-22: Scoliosis Research Society-22, ATR: Angle of Trunk Rotation, WRVAS: Walter Reed Visual Assessment Scale, *SD*: Standard Deviation, *p1*: Within Group Comparison (Time), *p2*: Group Comparison (Group), CI: Confidence interval.

changes in the SG patients were more significant than those in the LG. This finding is in line with the conclusion of a systematic review that reported reduction in vertebral angles and body asymmetries as a result of corrective, therapeutic Schroth exercises (Negrini et al., 2011).

In their study examining the effectiveness of Schroth and core exercises in 28 patients with AIS, Kocaman et al. reported that Schroth exercises were more effective than core exercises on CA, and sagittal and frontal alignment of the spine. Similarly, Kuru et al. found that supervised Schroth exercises could decrease the CA and ATR. In this regard, the current study's results may be said to be compatible with the relevant literature (Kocaman et al., 2021; Kuru et al., 2016). Many studies in the literature on exercise therapy for AIS have compared the effectiveness of different exercise techniques and scoliosis-specific exercises. However, in the current study, we compared the effect of two different scoliosis concepts, the results of which can be considered as important to clinicians and therapists working with AIS (Kocaman et al., 2021; Białek, 2011; Kuru et al., 2016). Additionally, there is a need for studies comparing different physiotherapeutic scoliosis-specific exercises (PSSE) techniques in order to have clearer and more specific information in this field and to determine which method is clinically more effective in which outcome measurement.

According to the Bunnell classification, an ATR degree between 0 and 3 is considered normal, and a degree above 3 is considered abnormal, and it has been stated that more detailed examinations are required for the diagnosis of scoliosis (Bunnell, 2005). In our study, the ATR scores of the participants before treatment were 4.8 and 4.5° in SG and LG, respectively; After treatment, it decreased to 2.2 and 3.7°. It could be said that this ATR decrease in individuals in SG is clinically significant.

Depending on the severity of the curve, physical and psychological problems can arise in patients with AIS (Monticone et al., 2014; Anwer et al., 2015). Different results have been reported in the literature regarding the effect of exercises on QoL in individuals with scoliosis (Grivas et al., 2006; Cheng et al., 2015; Sanders et al., 2003). However, due to the discrepancies between these studies, the effects of scoliosis-specific exercises on the patients' QoL remains unclear. In the current study, the pre-and post-treatment values of QoL were found to differ significantly. In most previous studies where an improvement in QoL was reported, the treatment period was at least 10 weeks in duration (Grivas et al., 2006; Lehnert-Schroth, 1992). A significant difference was found between the groups in terms of QoL before and after treatment. According to the comparison of the differences between the two groups, the change in QoL in the Lyon exercise group was more significant than in the Schroth exercise group. However, according to the data obtained from this study, it was unexpected that the QoL of the patients in the SG decreased compared to baseline. The current study reason for this difference is that the Schroth exercise group is in a more rigid exercise program than the Lyon exercise group, and that the QoL of individuals decreases as the intensity of the exercises increases. Also, the reasons for this may be that SG is too focused on auto-correction and understanding how scoliosis causes posture problems. The greater level of improvement in the LG may be attributable to the nature of the Lyon concept, which is primarily based upon patient-education and proprioception-enhancement. With regards to this topic, no reference was found in the literature that added to the discussion on the potential reasons. However, having compared the characteristics of both the Lyon and Schroth exercises, the current study has shown that the Lyon approach mainly emphasizes postural control and the adaptation of exercises for daily living activities. Therefore, it is among the expected results of the current study that the QoL of the participa Gür et al., 2017 nts was improved for the patients in the LG.

Anxiety is one of the main concerns in individuals with scoliosis due to adverse impact of the three-dimensional disorder on their physical appearance (Stępień et al., 2017). Reducing or eliminating this unfavorable esthetic impact is one of the primary goals of scoliosis treatment, as reported in a consensus by SOSORT (Negrini and Marchini, 2007b). Therefore, measuring the perception of the esthetic or cosmetic problem is considered important for patients and their families, and also for clinicians as a means to evaluating the outcome of any treatment (Gür et al., 2017). The WRVAS is sensitive to any improvement or worsening of the disorder of scoliosis (Gür et al., 2017; Kocaman et al., 2021). The literature reported that adding the Schroth exercise program to standard care can lead to an improved body image in patients with AIS (Negrini et al., 2011; Kim and HwangBo, 2016). A systematic review on this subject reported that corrective and therapeutic exercises, such as the Schroth method or Core stabilization exercises, were found to improve body symmetry in patients with AIS (Negrini et al., 2011). In the current study, the perceived trunk appearance was evaluated using the WRVAS, and considerable improvement was detected in both patient groups, in favor of significant changes seen in the SG. We think that the reason for the greater change in SG is that the change in Cobb angle is greater.

Due to the limitations of the current study, the results should be interpreted with some caution. First, despite having limited the study to patients all presenting with a Lenke 1 or 1A type curve, it is possible that some patients may have presented some different Schroth curve types or Lyon curve types classifications. Given we could not report the prevalence of different Schroth or Lyon curve types, this may limit the generalizability to other samples. Second, all of the participants had idiopathic scoliosis with a mild curve magnitude. Therefore, the study's findings cannot be generalized to other types of scoliosis (e.g., congenital or neuromuscular scoliosis), or to patients with different curve magnitudes. Third, although we stated at the beginning of the study that the study would be concluded with 31 participants with 80% power and 15% drop-out risk, it is important for such clinical studies to be conducted with a higher number of participants. Fourth, SOSORT recommends the application of PSSE treatments such as Schroth and Lyon techniques until skeletal maturation has been completed. The treatment for the participants included in our study will continue until their skeletal maturation is completed. However, our study only presents the effects of a 6-month treatment period (Negrini et al., 2011, 2016). Lastly, Although the sex distribution of the included is representative of the population, there are still too few males to examine the effects of the treatment separately by sex.

5. Conclusion

The study showed that Schroth exercises were more effective in reducing CA, WRVAS and ATR (main curve), Lyon exercises were shown to be more effective than Schroth exercises in improving the QoL of the patients. Both exercise methods may be used in the conservative treatment of mild AIS, depending on the purpose of the treatment. According to the final results of this study, it could be said that the Lyon exercise method is more effective on the quality of life, and the Schroth exercise method is more effective on posture, spinal alignment and perceived appearance in the short-term treatment for patients with AIS. Further studies are needed, however, with long-term follow-ups in patients with different types of scoliosis and with different curve types and curvature magnitudes.

Funding

None.

CRediT authorship contribution statement

Öznur Büyükturan: Investigation. **Mehmet Hanifi Kaya:** Writing – review & editing, Writing – original draft, Methodology, Investigation. **Halil Alkan:** Formal analysis, Data curation. **Buket Büyükturan:** Formal analysis. **Fatih Erbahçeci:** Supervision, Formal analysis.

Declaration of competing interest

The authors declare no conflict of interest.

Acknowledgments

None.

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