The efficacy of Schroth's 3-dimensional exercise therapy in the treatment of adolescent idiopathic scoliosis in Turkey

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ABSTRACT

Objective: To determine the effectiveness of 3-dimensional therapy in the treatment of adolescent idiopathic scoliosis.

Methods: We carried out this study with 50 patients whose average age was 14.15 ± 1.69 years at the Physical Therapy and Rehabilitation School, Hacettepe University, Ankara, Turkey, from 1999 to 2004. We treated them as outpatients, 5 days a week, in a 4-hour program for the first 6 weeks. After that, they continued with the same program at home. We evaluated the Cobb angle, vital capacity and muscle strength of the patients before treatment, and after 6 weeks, 6 months and one year, and compared all the results.

Results: The average Cobb angle, which was 26.10° on average before treatment, was 23.45° after 6 weeks, 19.25° after 6 months and 17.85° after one year ($p<0.01$). The vital capacities, which were on average 2795 ml before treatment, reached 2956 ml after 6 weeks, 3125 ml after 6 months and 3215 ml after one year ($p<0.01$). Similarly, according to the results of evaluations after 6 weeks, 6 months and one year, we observed an increase in muscle strength and recovery of the postural defects in all patients ($p<0.01$).

Conclusion: Schroth's technique positively influenced the Cobb angle, vital capacity, strength and postural defects in outpatient adolescents.

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Scoliosis, the most common deformity of the immature spine, is not simply an abnormal lateral curvature of the vertebral column. A rotational deformity of variable magnitude is nearly always present, and distortion in the sagittal plane may occur. If left untreated, this 3-dimensional growth-related deformity may sentence the younger patient to an adult life of pain, disability, low self-esteem, cardiorespiratory complications, and even premature death.[1-6] The general goal of treatment is to allow patients with scoliosis to attain osseous maturity with as straight and as stable a spine as possible, to avoid cardiopulmonary and neurological problems, and to improve the patients' aesthetic appearance and future quality of life. Appropriate early treatment will prevent or stop progression of the deformity and, in some instances, partially correct the existing deformity.[4] Various treatments have been proposed for idiopathic scoliosis, including surgery, traction, bracing, casting, electrical stimulation, physical exercise, and simple observation since the time of Hippocrates.[3,6-12] Nonoperative treatment, which is mainly synonymous with conservative treatment, is usually indicated for curves between 18° and 45°.[3,10] It is recommended that close monitoring of scoliotic children at 4-6-month intervals for curvatures up to 20° must be carried out. Growing adolescent curves

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greater than 40º-45º often require surgical correction and spinal fusion.[3,6-8,13] Exercise therapy aims to retard the increase in curvature, increase neuromotor control and stability of the spine, reduce biomechanically the postural collapse, prevent and treat secondary functional impairment (restrictive pulmonary disorder and reduced cardiopulmonary performance due to reduced mobility of the ribs), reduce pain, and improve appearance.[9,1] There are different specific exercise techniques for scoliosis, one of which is Schroth's 3-dimensional exercise therapy. It is based on sensorimotor and kinesthetic principles. The treatment program consists of correction of scoliotic posture and breathing pattern with the help of proprioceptive and exteroceptive stimulation and mirror control.[1,3,6,7,14,15] Using sensorimotor feedback mechanisms, the patients learn an individual correction routine and corrected breathing pattern. Using only active trunk muscle force, they learn to raise themselves as far as possible from a position of solely passive support by the spinal ligaments, which is thought to promote curve progression, and then to maintain the corrected posture in daily living activities. The correction is supported by "rotational breathing", which is integrated in the corrective routine. By selective contraction of the convex area of the trunk, inspired air is directed to concave areas of the thorax, and the ribs are mobilized in these regions.[14] According to Schroth, postural disorder is first corrected by skeletal correction: pelvis backwards, trunk forwards, creating the opposite shape. The same principle is followed when correcting the scoliotic static in the frontal plane with lateral displacement of individual body sections. The pelvis, which is unilaterally protruding, is taken in towards the line of gravity. This results automatically in a more erect trunk. Only this change in posture makes it possible to use rotational breathing effectively. When the trunk and spine have reached their optimal length, the trunk sections, which are rotated against each other, are able to move without mutual interference.[14] Katharina Schroth divided the trunk into 3 blocks, which can be shifted against each other. She recognized that the pelvic and the shoulder girdles are rotated in the same direction and that the middle block, the rib cage, is oriented in the opposite direction – in the sagittal plane as well as in the frontal plane. The more these blocks shift against each other, namely, the more they deviate from a vertical line; the more they rotate also in the transverse plane (about the vertical body axis). The body becomes less and upright and "crumbles," as all parts of the body that deviate from the vertical line are drawn downwards by gravity. For this reason, active extension is a prerequisite of successful exercising. The elongation is connected to active curve correction and realignment of trunk segments that have deviated laterally. This is completed by active de-rotation of the 3 trunk segments rotated against each other. This is achieved by appropriate starting positions for exercises as well as by rotational breathing.[14] Publications showing the results of studies using Schroth's technique have increased in the last 10 years.[6,9,14,16] However, those showing the effects of Schroth's technique in outpatients are rather limited.[9] Therefore, this study was carried out to determine the effects of Schroth's 3-dimensional exercise therapy in outpatients with adolescent idiopathic scoliosis (AIS).

Methods. Sixty-eight patients with right thoracic AIS participated in our study at the Physical Therapy and Rehabilitation School, Hacettepe University, Ankara, Turkey, from 1999 to 2004. However, 18 patients who were not compliant dropped out of the study. Thus, 50 patients (12 boys, 38 girls) were included in the study. All patients were volunteers. Patients with tumors in any part of the body, any disorder in systems such as cardiovascular, renal, or pulmonary system, and those undergoing spinal surgery or with indications for spinal surgery were excluded. None where wearing a brace. Patient ages ranged from 11-17 years, with a mean of 14.15 ± 1.69 years. The distribution of patients according to the apex of scoliosis is shown in **Table 1.** The average Cobb angle of the curvatures was 26.10 ± 4.69° (between 20º and 35º) **(Table 1).** Before the treatment program, the entire spinal column of each patient from occiput to sacrum was x-rayed in the anterior-posterior direction in the standing position to designate the shape and apex of scoliosis, and the Cobb angle of curvature of the patients was calculated. In addition, posture analysis,[17] vital capacity evaluation,[18] and muscle tests[17] of the body

Table 1 - The physical characteristics of patients, and distribution of patients according to apex of scoliosis.

Characteristics n=50	Mean ± SD	(Range)	Apex of scoliosis	n (%)
Age (year)	14.15 ± 1.69	(11-17)	T5	2(10)
Weight (kg)	42.85 ± 5.78	(30.5-53)	T6	3(15)
Height (cm)	162.66 ± 66	(150-197.5)	T7	5(25)
Cobb angle (degree)	26.10 ± 4.69	(20-35)	T8	4(20)
			T9	3(15)
			T10	2(10)
			T11	1 (5)

T - thoracic vertebrae

muscles, and muscles surrounding the scapula (back extensors, anterior trunk flexors, lateral trunk flexors, musculus serratus anterior, musculus trapezius, musculus rhomboideus major and minor) were carried out. In assessing muscular strength, Dr. Lovett's manual muscular strength tests were applied (scores range from 0-5).[17] To evaluate the vital capacities of the patients, they were asked to blow up a balloon with a maximum expiration immediately after a maximum inspiration. The circumference of the balloon was then measured in centimeters, and the vital capacity was calculated in milliliters according to the scale described by Hansen.[18] The patients started Schroth's 3-dimensional exercise treatment program the day after the evaluation. Schroth's exercises are begun in an asymmetric position to maximize the magnitude of correction, in an attempt to achieve the maximum possible trunk symmetry. These exercises include de-rotation, de-flexion and stretching exercises for providing vertebral regularity, torsional respiration exercises and exercises for strengthening the abdominal, back, leg and foot muscles. One of the specific exercises described by Schroth is called muscle cylinder. These exercises are asymmetric and strengthen the muscle in the "weak spot" below the hump of the ribs on the convex side. During the exercise the correction pads, which are filled with 250 mg of sand, rice, and so forth, (dimensions of 13 x 17 cm), are used to encourage the spine to de-rotate. These pads provide localized sustained pressure during floor exercises for mobilization of rib prominences or other torso and lumbar asymmetries. Manual correction is used for some exercises. Passive transverse forces are applied, as needed (depending on curvature pattern, flexibility and magnitude), using a vertical frame with adjustable belts.[3,18] In the course of the exercise, ordinary household objects, such as tables and chairs, can be used as well as wall bars and a horizontal bar. Mirrors enable the patients to monitor their progress and achieve maximum correction. Tactile stimuli, for example, in the concave region of the thorax to indicate the desired direction of breathing, provide the exteroceptive stimulation necessary to achieve the required correction.[1,3,6,14,18] In our study, this program was run for one year as an outpatient rehabilitation program, as we do not have inpatient facilities. For the first 6 weeks, the patients implemented this program under our supervision for 4 hours a day, 5 days a week. At the same time, this program was taught to their families. Later they carried out the same program at home. During this period, they combined their daily living activities with these exercises. For the program to be implemented correctly, all patients were invited to our outpatient clinic once every 2 weeks during the first 6 months, and program compliance was checked. After that, all patients were examined once every 2 months for the remaining 6 months. One year later, the study was terminated. All evaluations, which were performed before treatment, were repeated after 6 weeks, 6 months and one year, and the results were compared.

Statistical analysis. The results obtained before treatment, and 6 weeks, 6 months and one year after treatment were compared using Friedman statistical analysis. While the muscle test results of the subjects were being compared, statistical analysis was not performed separately for each of muscle test results; only the average muscle strength of muscles located on the right and left side, and muscle strength of the back extensor and anterior trunk flexor muscles were analyzed. The postural defects of the subjects were compared by applying Friedman statistical analysis to the total number of postural defects seen. A p-value of 0.05 was chosen.

The software package SPSS 11.00 was used for the statistical analysis.

Results. Based on the results obtained after 6 weeks, 6 months and one year, a decrease in the Cobb angle, an increase in muscle strength and vital capacity and an improvement of postural defects in all subjects were achieved and these results are statistically significant ($p<0.01$), **(Table 2)**, **(Figures 1-3)**. The Cobb angle, on average was 26.10° before treatment, decreased to 17.85° after one year and vital capacities increased from a mean of 2795 ml to 3215 ml. Similarly, while the average number of postural defects per person was 5 before treatment, this number was one after one year. **Table 3** shows the distributions of postural defects seen in the subjects before and after treatment. When we examined increases in muscle strengths, we observed a statistically significant increase in all muscles, but this increase was greater in the convex side muscles.

Discussion. Scoliosis is a 3-dimensional deformity in which the spine deviates from its normal sagittal and coronal positions in the upright human posture and becomes fixed in this unbalanced posture. The mechanical imbalance inherent in scoliosis, irrespective of its cause, results in asymmetric loading, which constitutes a vicious cycle with an inevitable tendency to worsen with time.[19] Scoliosis treatment by postural-balancing physiotherapy has a long tradition in Europe. Spain, France, Italy, and Germany employ physiotherapy in specialized centers. In Eastern Europe, especially in Russia, boarding schools offer an environment where scoliosis patients learn exercise-based treatment strategies in a therapeutic group setting.[3] In Germany, Schroth's program and exercises are commonly performed. Internationally, side shift

Table 2 - Comparison of Cobb angle, vital capacity, muscle strength and number of the postural defects of patients after treatment.

Parameter (N=50)	Pre-treatment (Mean ± SD)	After 6 weeks (Mean ± SD)	After 6 months (Mean ± SD)	After 1 year (Mean ± SD)	Friedman Test χ^2	df	*p*
Cobb angle (degree)	26.10 ± 4.69	23.45 ± 5.09	19.25 ± 3.86	17.85 ± 358	59.714	3	0.00*
Vital capacity (ml)	2795 ± 402.95	2956 ± 428.83	3125 ± 416.03	3215 ± 428.02	59.223	3	0.00*
Muscle strength							
Anterior trunk flexors	3.63 ± 0.54	4.35 ± 0.42	4.93 ± 0.18	5.00 ± 0.00	56.483	3	0.00*
Back extensors	3.10 ± 0.58	3.53 ± 0.41	4.43 ± 0.35	4.93 ± 0.00	52.462	3	0.00*
Total muscle strength							
Right	3.26 ± 0.52	3.92 ± 0.41	4.77 ± 0.12	4.91 ± 0.00	59.455	3	0.00*
Left	4.02 ± 0.28	4.60 ± 0.20	4.91 ± 0.07	4.98 ± 00	58.701	3	0.00*
Number of postural defects	4.55 ± 1.73	2.15 ± 1.35	1.65 ± 1.27	1.10 ± 0.97	51.787	3	0.00*

* - $p<0.01$

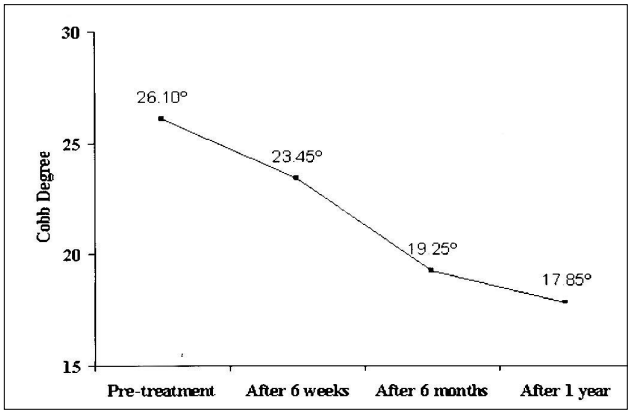

Figure 1 - Patients' Cobb degrees.

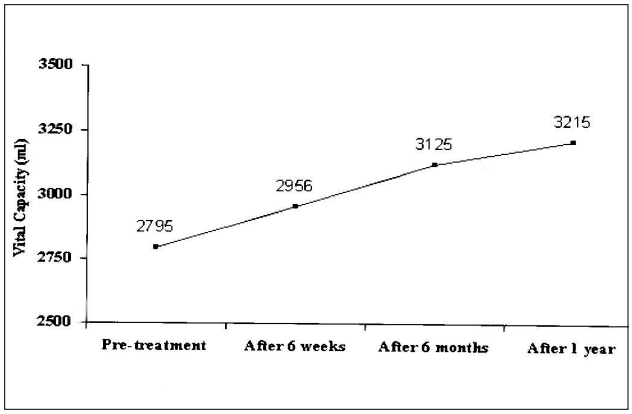

Figure 2 - Patients' vital capacities.

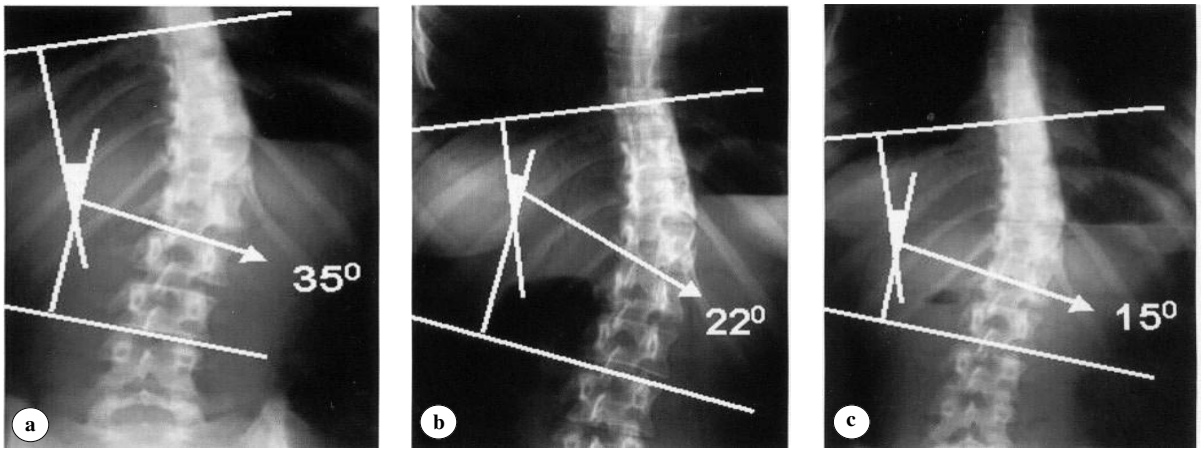

Figure 3 - X-ray of a 14-year-old girl with thoracic curvature. (**a**) Cobb degree, before treatment (**b**) Cobb degree, 6 months later and (**c**) Cobb degree, one year later.

Table 3 - The distribution of postural defects of patients.

Postural defects (N=50)	Pre-treatment n (%)	After 6 weeks n (%)	After 6 months n (%)	After 1 year n (%)
Lateral balance of trunk	10 (50)	0 (0)	0 (0)	0 (0)
Pes planus	9 (45)	9 (45)	9 (45)	9 (45)
Tibial torsion	8 (40)	8 (40)	8 (40)	8 (40)
Genu varum	2 (10)	2 (10)	2 (10)	2 (10)
Lateral pelvic tilt	7 (35)	5 (25)	3 (25)	0 (0)
Unequal shoulder height	16 (80)	9 (45)	7 (45)	0 (0)
Rolling shoulder	9 (45)	0 (0)	0 (0)	0 (0)
Scapular abduction	15 (75)	9 (45)	7 (45)	3 (15)
Anterior tilt of head	14 (70)	0 (0)	0 (0)	0 (0)

exercises are in use in scoliosis intensive rehabilitation (SIR). The SIR employs an individualized exercise program combining corrective behavioral patterns with physiotherapeutic methods, following principles described by Lehnert-Schroth.[3] Schroth's technique, which is increasing in popularity worldwide, has been in use in Turkey for the last 7 years. Originally, Schroth's technique is an intensive course of inpatient physiotherapy (4-6 weeks - 6-8 hours per day).[1,3,6,7,14,15,20] At the end of inpatient treatment, recommended at-home follow-up treatment includes 3-4 exercises for 30 minutes daily to maintain the improved postural balance. Therapists throughout Germany receive training in the Schroth clinic approaches so that local outpatient resources are available to patients after discharge.[3,6]

In 1992, Weiss[14] published the results obtained from 118 patients with AIS who had been treated with an intensive inpatient physiotherapy program with Schroth's technique from 1984 to 1988: 48.3% had thoracic scoliosis, 37.3% had double curves, 12.9% had lumbar scoliosis, and 13% had thoraco-lumbar scoliosis. The average follow-up period was 31.5 months. The mean initial Cobb angle was 31° and the mean final angle was 34.6°. In 16.1% of patients, progression was evident; 68.7% had stabilized and 15.2% showed an improvement of more than 5°. An increase of ≥ 5° in the most severe curvature was used to define progression.[6] Compared with the natural history of the disease, he stated that an increase in curvature in patients with idiopathic scoliosis could be retarded by means of this specific exercise program.[14] In another study by Weiss[21] radiographs were obtained under standard conditions in 107 patients with idiopathic scoliosis immediately before and immediately after a 4-6-week inpatient exercise program at the Katharina-Schroth Hospital. The average angle of curvature measured by the Cobb technique was 43.06° before treatment and 38.96° after treatment. An improvement in the curve of 5° or more was found in 43.9% of the patients, 53.3% were unchanged, and in 2.8% the curve had increased by 5° or more. Overall, the improvements in curvature were highly significant. Weiss stated that these results show that even in severe scoliosis the magnitude of the curve can be reduced by a specific rehabilitation program of physiotherapy.

Weiss et al[6] also evaluated the incidence of progression in patients receiving inpatient rehabilitation treatment in a prospective follow-up study of 181 patients with idiopathic scoliosis. Curvature patterns included thoracic (35%), thoracic lumbar (7%), lumbar (28%), and double major (27%). The average Cobb angle was 27° before the study. The treatment was continued for 4-6 weeks, and the average follow-up period was 33 months. The results of their study are consistent with the possibility that a supervised program of exercise based therapies can reduce the incidence of progression in children with idiopathic scoliosis. Although this technique is an intensive course of inpatient physiotherapy, this approach includes outpatient physiotherapy beginning at 15° according to Cobb. Specific exercises are performed on an outpatient basis for patients with curvatures of 15–20°. The SIR is recommended for curvatures of 20–30°, with or without bracing, depending on the prognosis.[6]

Rigo et al,[22] presented patients regularly treated with Schroth's 3-dimensional scoliosis treatment program. They participated in an outpatient program, twice a week, for 2 hours. Forty-three patients with 19.5° Cobb angles exercised for 19.5 ± 8.5 months (minimum 3 months) and were evaluated retrospectively. A curvature increase of more than 5° during the follow-up period was shown in 11.6% of cases, while 44.2% of patients had

stabilized, and 44.2% showed improvements of more than 5°.

In our study, we treated 50 patients with right thoracic scoliosis with Schroth's 3-dimensional technique in our outpatient clinic. Schroth's technique was applied under our supervision for 4 hours a day, 5 days a week in the first 6 weeks, and later the patients continued with the same program at home. The follow-up period was one year. The average angle of curvature as measured by the Cobb technique was 26.10° before treatment, 23.45° after 6 weeks' treatment, 19.25° after 6 months, and 17.85° after one year. These results were highly significant. After 6 weeks, in only one patient did the Cobb angles not change; none of the patients got worse and recovery [minimum 1° (4.35%), maximum 5° (20%)] was observed in all the other patients. After 6 months, an improvement in the Cobb angles of all the patients was observed [minimum 4° (12.50%), maximum 11° (39.29%)]. After one year, an improvement in all the patients was seen [minimum 5° (25%), maximum 13° (40%)]. These results indicate that this program, which included a 6-week supervised program of exercise-based therapies and a 46-week unsupervised program, can reduce the incidence of progression in children with idiopathic scoliosis. Similarly, a statistically significant recovery was observed in the muscle strengths of our patients by the end of the treatment. One of the goals of treatment in scoliosis is to improve the patients' aesthetic appearance. In parallel with the decrease in the Cobb angle and increases in the muscle strengths (especially at the convex side), the postural defects of our patients were also improved.

In curvatures involving the thoracic spine, reduced chest wall mobility and impaired excursion occur as secondary effects of reduced spinal flexibility.[5,19] A resultant loss of rib-cage–spine coupling patterns leads to restrictive lung disease secondary to reduced chest wall compliance (CCW); CCW and vital capacity are inversely correlated with curvature magnitude down to a Cobb angle of 10°. Even when resting vital capacity is found to be normal, a respiratory challenge reveals reduced exercise capacity even in children with mild curvatures (Cobb angle 5°–20°).[3] In Schroth's technique, the correction is supported by 'rotational breathing' exercises, an integral part of the regime: by selective contraction of convex areas of the trunk, the inspired air is directed to the concave areas of the chest and the ribs to lengthen and mobilize soft tissues in these regions.[3] At the end of our study, a statistically significant increase in the vital capacities of all the subjects was observed. This result indicates the efficiency of rotational breathing exercises in our patients. While the vital capacity of the subjects with an average of 14.15 ± 1.69 years of age was 2795 ± 402.95 ml before treatment, it was 3215 ± 416.03 ml after one year of treatment. Although a significant increase in the vital capacity of our subjects was determined in the first 6 months, a smaller increase was found between 6 months and one year. This may be due to the subjects' reaching the normal vital capacity according to their ages (normal vital capacity for 14 years old is 3050 ml, and for 15 years old 3300 ml).[18]

Schroth's technique is difficult for the patients to perform. It involves a very intensive program. For this reason, we lightened the program, and applied it 4 hours a day as an outpatient program. Despite this, some patients were not compliant. Since the success of this technique depends on correct use, we excluded them from the study, and examined the remaining patients frequently throughout one year. At the end of study, we obtained significant results. In any case, this outpatient physiotherapy program consisting of Schroth's 3-dimensional exercises therapy was shown to influence positively parameters such as Cobb angle, vital capacity, strength and postural defects in AIS patients. Clearly this program is useful in AIS patients if they are compliant, and the number of publications on the use of Schroth's technique in outpatients, which is quite small, should be increased.

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