The Effect of an Exercise Program on Vital Capacity and Rib Mobility in Patients with Idiopathic Scoliosis

HANS RUDOLF WEISS, MD

All 813 patients with idiopathic scoliosis who completed their first Schroth physiotherapeutic rehabilitation program at the Katharina Schroth Hospital between 1984 and 1987 were reviewed. The patients were divided into four age groups. In Group I (10–13 years, N = 278), vital capacity in patients treated for the first time improved by 18.94% (445 ml). In Group II (14–17 years, N = 264), the average increase in vital capacity after initial treatment was 16.33% (497 ml). In Groups III (18–24 years, N = 123) and IV (> 24 years, N = 148), the corresponding increases were 15.11% (501) and 13.77% (394 ml), respectively. In the 256 patients receiving repeat treatment, the increases in vital capacity in the respective age groups amounted to just more than half those in the patients treated for the first time. The average increase in chest expansion was more than 20% in all groups at all measuring points. These findings show that a course of inpatient treatment by the Schroth method can lead to an increase in vital capacity and chest expansion so that, even in adult scoliosis patients, effective treatment of the associated restrictive ventilatory disorder is possible. [Key words: scoliosis, physiotherapy, vital capacity, rib mobility, rehabilitation]

IT IS A KNOWN FACT that adult scoliosis patients with a Cobb angle of more than 60° are threatened by pulmonary hypertension and restriction of cardiopulmonary performance.[4,10,11,18,21] Growth impairment of the rib cage and lung[15,16] and reduced inspiratory muscle strength[20] have been reported in patients with idiopathic scoliosis. It is frequently assumed, however, that respiratory impairment is negligible in patients with Cobb angles of less than 60°. Smyth et al,[19] DiRocco and Vaccaro[3] and Weber et al[21] already found marked impairment of respiratory mechanics and cardiopulmonary performance in scoliosis patients with Cobb angles of less than 35°. The scoliotic breathing pattern, which leads to an increase in curvature, particularly in rotation (Figure 1A),[8,9] and the restricted rib mobility[9,14] are starting points for prevention and rehabilitation in the management of patients with scoliosis. Measurement of respiratory excursions in adolescents with thoracic scoliosis by the use of a special apparatus permitting maximum fixation of the shoulder and pelvic girdles has already shown that alteration of the scoliotic breathing pattern is possible.[24] In "rotational breathing" exercises, the patient learns to direct his breath consciously to the concave regions of the thorax by deliberately tensing the muscles in the convex regions (Figures 2 and 3). This leads to a corrected breathing pattern (Figure 1B).

Vital capacity (VC) is a very suitable index for characterization of the restrictive ventilatory disturbance in scoliosis patients.[6,7] It decreases as angle of curvature increases.[2] There is a linear relationship between the restriction of VC and right ventricular work.[14] The greater the impairment of VC, the more the right side of the heart needs to work. For this reason, we can expect that an increase in VC will also improve the cardiopulmonary situation.

Neither Bjure et al[1] nor Götze[5] were able to demonstrate an effect of physical training on VC in scoliosis patients, although both of their studies did demonstrate an increase in cardiopulmonary performance. Götze et al[6] also showed, however, that a program of specific exercises lasting several weeks, as developed by Schroth, is able to produce highly significant increases in cardiopulmonary performance as well as significant increases in VC.

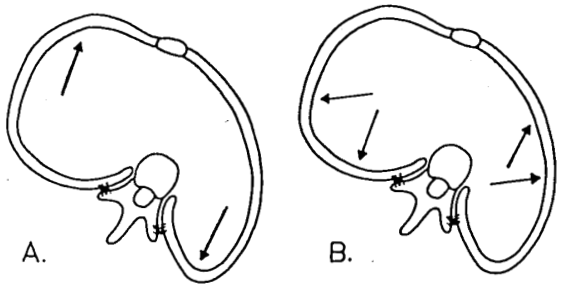

Fig 1. A, The scoliotic breathing pattern (as modified by Henke[8]). **B,** Corrected breathing pattern according to Schroth.

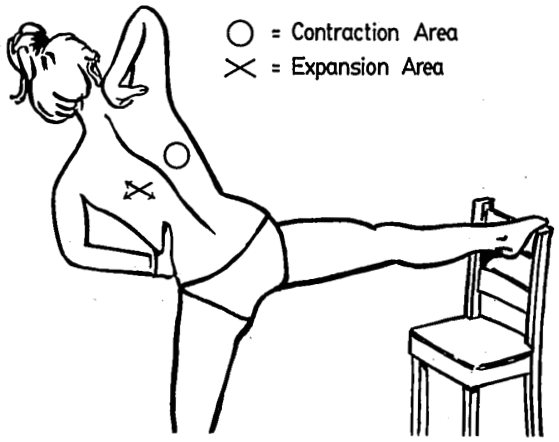

Fig 2. Patient during a Schroth exercise. Contraction of the muscles in the region of the rib hump alters the breathing movement and thus permits expansion on the concave side.

From the Katharina-Schroth-Klinik, Zentrum für konservative Skoliosebehandlung, Sobernheim, Germany.

Submitted for publication April 21, 1989, and revised July 13, 1990.
The author is grateful to Gunther Agotai for the statistical analysis.

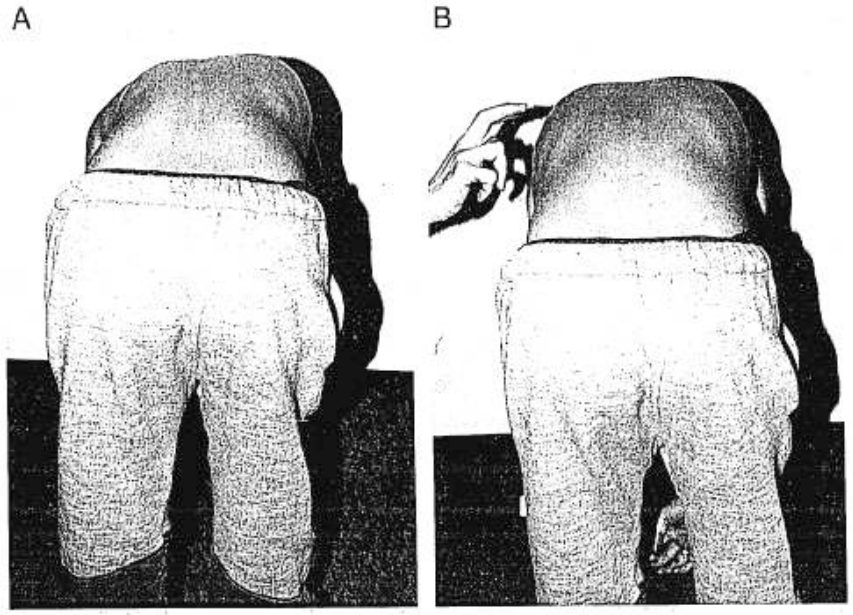

Fig 3. Patient bending forward. **A,** Resting expiratory position. **B,** Derotation movement by means of breathing. (From Lehnert-Schroth.[13])

MATERIALS AND METHODS

All scoliosis patients treated at the Katharina Schroth hospital between 1984 and 1987 were reviewed for changes in VC and chest expansion after an in-patient treatment period of 4–6 weeks. The patients were divided into four age groups. In addition, patients were divided into two subgroups: patients treated for the first time and patients receiving repeat treatment. The average Cobb angle for patients treated for the first time was 38.3° (SD = 24) and 41.2° (SD = 24) for patients receiving repeat treatment. The repeat treatments were performed after an average time of 37 months (SD = 25).

The average Cobb angles for the respective age groups were as follows:

Group I (patients aged 10–13 years): 30.1° (SD = 21.5) for patients receiving first treatment; 34.3° (SD = 18.2) for patients receiving repeat treatment.

Group II (patients aged 14–17 years): 30.5° (SD = 16.7) for patients receiving first treatment; 36.3° (SD = 18.9) for patients receiving repeat treatment.

Group III (patients aged 18–24 years): 34.9° (SD = 19.8) for patients receiving first treatment; 41.7° (SD = 27.6) for patients receiving repeat treatment.

Group IV (patients >24 years): 49.3° (SD = 29.1) in patients receiving first treatment; 59.2° (SD = 26.9) for patients receiving repeat treatment.

Measurements of vital capacity were taken at the beginning and end of a first or repeat course of in-patient treatment. In each case three measurements were made, each time with the patient standing under the same postural conditions according to exact instructions. Almost all the patients were already familiar with the technique of blowing into a spirometer at the time of the initial treatment because spirometry is part of the diagnostic program employed for the assessment of pulmonary function in scoliosis patients in Germany. All measurements were recorded by the same trained staff members, who have been familiar with the procedure since the end of the 1970s. Only the highest of the three vital capacities obtained were evaluated.

Measurement of VC at the Katharina Schroth hospital is performed routinely using a Hospal resistance-free pulmonary function analyzer (Hospal Medizintechnik, Nürnberg, Germany). The values were automatically converted to body temperature pressure saturated.[12] Chest expansion was determined as the difference between the trunk circumference at maximum expiration and maximum inspiration measured under the armpits at the junction between the xiphoid process and the body of the sternum and at the waist. The measurements were accurate to 5 mm. Measurements were taken by the same qualified staff members using a conventional tape measure marked in millimeters. Although the circumference measurements themselves have a relative measurement error depending on the exact point of measurement, such an error is largely ruled out by consideration of only the differences between two circumferences measured at the same point under the same conditions.

At the Katharina Schroth Hospital, radiographs are not taken routinely before and after a 4–6-week course of in-patient treatment. On the one hand, the timing of the in-patient treatment at this hospital often does not coincide with the radiograph schedule of the orthopaedic surgeon looking after the patient at his home town; on the other hand, it is scarcely acceptable to take radiographs in such close succession. For these reasons, no data on changes in angle of curvature in the course of in-patient treatment at this hospital are provided. According to a retrospective follow-up study,[25] however, there is evidence that the rehabilitation program described can have a positive influence on curvature in idiopathic scoliosis.

THE THREE-DIMENSIONAL SCOLIOSIS TREATMENT DEVELOPED BY SCHROTH

The three-dimensional scoliosis treatment developed by Schroth is based on sensomotor and kinesthetic principles. The treatment program consists of correction of the scoliotic posture and correction of the scoliotic breathing pattern with the help of proprioceptive and exteroceptive stimulation and with mirror control. In an intensive in-patient treatment program, the patient exercises for 6–8 hours daily and, with the help of the sensomotor feed-back mechanisms, learns his individual correction routine and corrected breathing pattern. By using active trunk muscle force only, the patient learns to raise himself as far as possible from the position of solely passive support by spinal ligaments said to promote curve progression. He also learns to maintain this corrected posture in his activities of daily living. The correction is supported by rotational breathing, which is integrated in the corrective routine. By selective contraction of convex areas of the trunk, the inspired air is directed to concave areas of the chest and the ribs mobilized in these regions.[22,23] The patients exercise in groups for 2

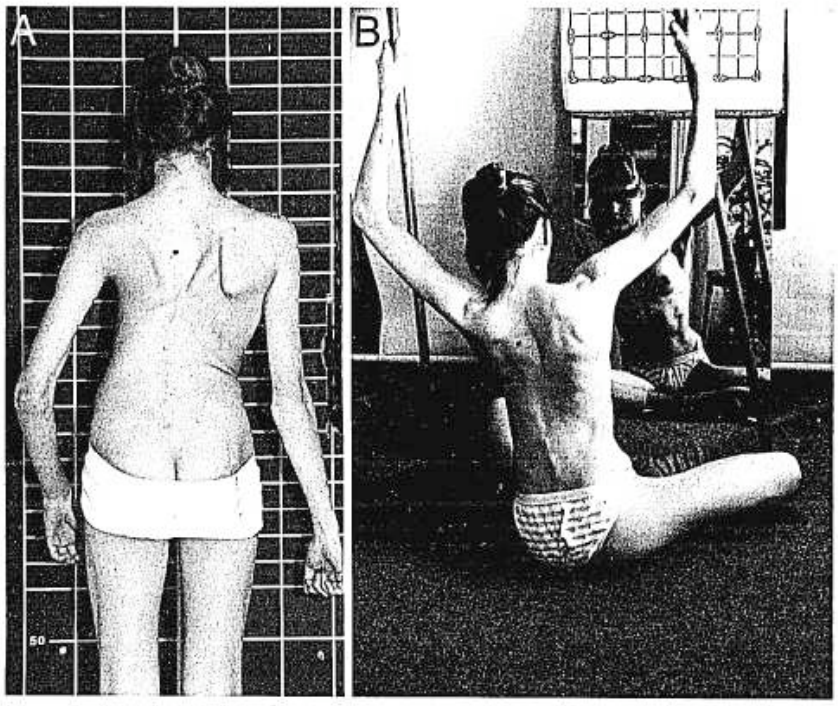

Fig 4. Scoliosis patient (Cobb angle 90°) before **(A)** and during **(B)** performance of an exercise from the Schroth program in front of a mirror. Note should be taken of the lateral inclination to the side of the thoracic concavity for reflex activation of the postural musculature.

hours in the morning and 2 hours in the afternoon and receive shorter individual training sessions in between. Depending on their individual curve patterns, the patients are also assigned to special exercise groups for an additional 2 hours daily. Additional individual treatment and massage round off the daily schedule.

The exercise program itself follows the principles described by Lehnert-Schroth.[13] The exercises are started with patients in an asymmetric position in an attempt to achieve maximum possible trunk symmetry (Figure 4). Ordinary household objects, such as tables and chairs, can be used for the exercises. We also use wall bars and a bar. Mirrors enable the patients to monitor their progress at any time and thus achieve optimum correction. In both the individual and group work the initial assistance given by the therapist is very important. Tactile stimuli, eg, in the concave region of the thorax to indicate the direction of breathing, give the patient the exteroceptive stimulation necessary for the desired correction.

At the end of such a course of in-patient treatment, the patient should be capable of independently assuming his personal corrected postural stereotype, without the assistance of the therapist and without mirror control, and should be able to maintain this position in his daily activities.

After an intensive course of in-patient treatment lasting several weeks, the scoliosis patient is discharged with a short daily exercise routine to perform on his own under the regular supervision of a physiotherapist in the community.

RESULTS

In the individual age groups, VC was calculated as a percentage of the expected normal value by the use of arm span as an index of expected height[17]:

In Group I, the average initial VC was 81.4% (SD = 24.3) of the normal value in patients treated for the first time and 80.8% (SD = 16.1) of the normal value in patients receiving repeat treatment.

In Group II, the average initial VC was 81.6% (SD = 19.5) of the normal value in patients treated for the first time and 82.9% (SD = 19.5) of the normal value in patients receiving repeat treatment.

In Group III, the average initial VC was 86.0% (SD = 20.3) of the normal value in patients treated for the first time and 90.9% (SD = 22.0) of the normal value in patients receiving repeat treatment.

In Group IV, the average initial VC was 91.6% (SD = 24.8) of the normal value in patients treated for the first time and 88.2% (SD = 23.7) of the normal value in patients receiving repeat treatment (Figures 5 and 6).

For the sake of clarity the changes in VC and chest expansion are presented in tabular form (Tables 1–4). These tables show the absolute

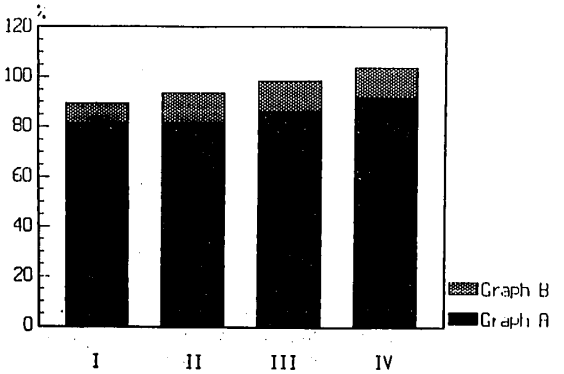

Fig 5. Vital capacity as percentage of expected normal value before (Graph A) and after (Graph B) a first course of inpatient treatment by the Schroth method.

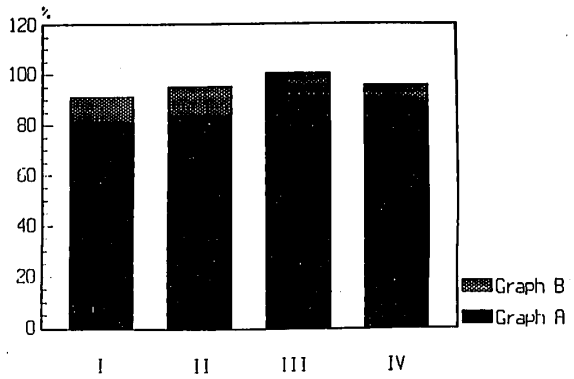

Fig 6. Vital capacity as percentage of expected value before (Graph A) and after (Graph B) a repeat course of inpatient treatment by the Schroth method.

values and percentage changes without reference to normal values for VC. The group distribution with regard to chest expansion is identical to that in the measurement of VC. The significance level is $P < 0.001$ for all the values given and is thus not mentioned separately in the tables.

The increases in VC in patients receiving repeat treatment in Group IV (N = 14) were not significant, amounting to 2.23% of the baseline value, or 71 ml (Table 1). In view of the small number of treatments, however, this result cannot be regarded as representative. The changes in VC in the various age groups are also shown in Figures 7–10. These figures show the changes in VC after 4–6 weeks of treatment as percentages of the respective baseline values (Figures 7 and 8) and the absolute changes in VC in milliliters (Figures 9 and 10) without reference to normal values. The absolute vital capacities were not corrected for growth because only the changes in VC during a course of treatment lasting 4–6 weeks were being investigated, and no significant growth can be expected in this short observation period.

Because the patients receiving first treatment and those receiving repeat treatment were for the most part not identical (not all patients receiving first treatments had a repeat treatment, some repeaters having first treatments before 1984), a meaningful follow-up study of this patient population could not be made.

Table 1. Changes in Vital Capacity in Patients With Idiopathic Scoliosis in the Various Age Groups Under the Influence of a Course of Inpatient Physiotherapy

Group	*Increase (%)*	*Confidence Interval (%)*	*Increase (ml)*	*Baseline Value (ml)*	*Posttreatment Value (ml)*
I F	18.94	15.40-22.47	445	2,499	2,944
I R	10.74	7.06-14.43	264	2,694	2,958
II F	16.33	13.11-19.56	494	3,195	3,689
II R	8.46	4.03-12.88	258	3,341	3,599
III F	15.11	10.19-20.02	501	3,608	4,109
III R	7.14	1.03-13.26	221	3,534	3,755
IV F	13.77	9.94-17.59	398	3,247	3,644
IV R	2.23	−3.38-7.84	71	3,511	3,582

F = first treatment; R = repeat treatment.

Table 2. Increases in Chest Expansion Measured under the Armpits in Patients with Idiopathic Scoliosis in the Various Age Groups

Group	*Increase (%)*	*Confidence Interval (%)*	*Increase (cm)*	*Baseline Value (cm)*	*Posttreatment Value (cm)*
I F	28.78	23.35-34.20	1.26	4.79	6.23
I R	30.03	21.14-38.91	1.37	5.24	6.61
II F	30.27	25.09-35.54	1.41	5.20	6.61
II R	26.10	18.79-33.41	1.28	5.44	6.73
III F	32.88	24.79-40.98	1.57	5.29	6.86
III R	25.28	11.08-39.48	1.28	5.29	6.86
IV F	33.33	20.34-46.32	1.37	4.98	6.35
IV R	32.81	8.33-57.28	1.64	5.21	6.86

Table 3. Increases in Chest Expansion Measured at Junction Between Xiphoid Process and Body of Sternum in Patients with Idiopathic Scoliosis

Group	*Increase (%)*	*Confidence Interval (%)*	*Increase (cm)*	*Baseline Value (cm)*	*Posttreatment Value (cm)*
I F	29.04	24.09-33.99	1.29	4.89	6.18
I R	25.41	17.59-33.22	1.16	5.20	6.36
II F	30.05	24.75-35.35	1.42	5.27	6.69
II R	24.10	16.02-32.18	1.19	5.48	6.67
III F	31.43	24.03-38.83	1.56	5.47	7.02
III R	25.18	12.94-37.43	1.34	5.76	7.10
IV F	31.50	22.80-40.21	1.34	4.99	6.34
IV R	42.14	3.59-80.70	1.79	4.57	6.36

Table 4. Increases in Chest Expansion Measured at the Waist in Patients with Idiopathic Scoliosis

Group	Increase (%)	Confidence Interval (%)	Increase (cm)	Baseline Value (cm)	Posttreatment Value (cm)
I F	45.09	37.82-52.35	1.55	3.91	5.46
I R	30.14	22.15-38.13	1.19	4.52	5.72
II F	41.18	34.65-47.70	1.54	4.20	5.74
II R	28.34	20.39-36.30	1.23	4.77	6.00
III F	39.25	28.31-50.19	1.56	4.58	6.14
III R	38.79	18.73-58.85	1.55	4.48	6.03
IV R	42.77	31.12-54.42	1.56	4.38	5.49
IV R	28.10	1.35-57.54	1.29	4.79	6.07

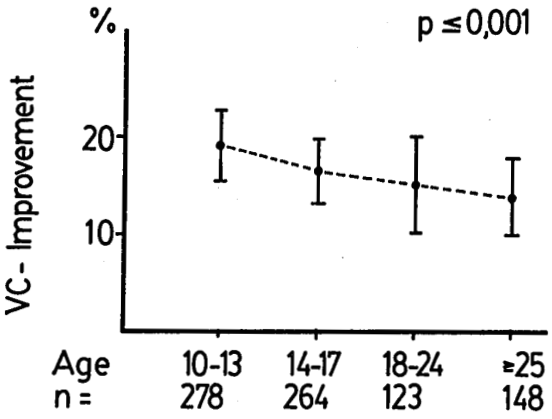

Fig 7. Increases in vital capacity in percentage of the baseline value after a first course of inpatient treatment by the Schroth method.

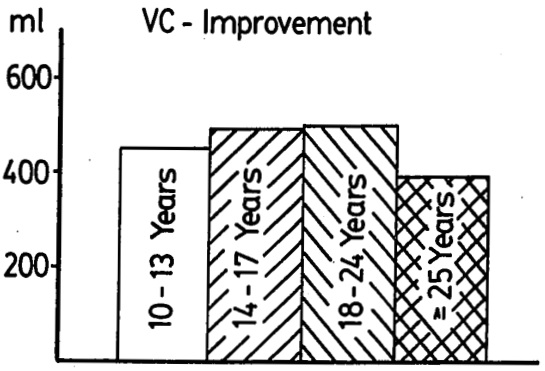

Fig 9. Increases in vital capacity in milliliters in scoliosis patients after their first course of inpatient treatment by the Schroth method.

No correlation between increase in VC and increase in chest expansion was found in any of the age groups. In this investigation, the increases in chest expansion at the three points cited were added, and the value thus obtained related to the increases in VC.

In the patients treated for the first time, there was a slight positive correlation between Cobb angle and age ($r = 0.407$). In addition, a slight negative correlation was found between Cobb angle and VC ($r = -0.306$). In the patients treated for the first time in Group IV, there was also a slight negative correlation between increase in VC and Cobb angle ($r = -0.2209$).

DISCUSSION

In a small sample of adolescent scoliosis patients treated repeatedly in the Katharina Schroth Hospital, Götze et al[6] found an increase in VC of 11% after a treatment period of 4 weeks. This is in keeping with findings in patients receiving repeat treatment in this study. A 10.7% increase in VC was also found in a long-term study reported elsewhere.[23] In the patients treated for the first time, however, the percentage increases of 18.94% obtained in this study and 20.85% in the above-mentioned long-term study[23] were almost double. At any rate, a course of in-patient treatment by the Schroth method appears to be superior to a

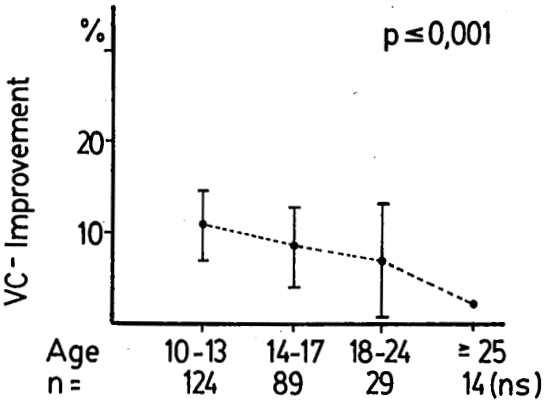

Fig 8. Increases in vital capacity in percentage of the baseline value after a repeat course of treatment.

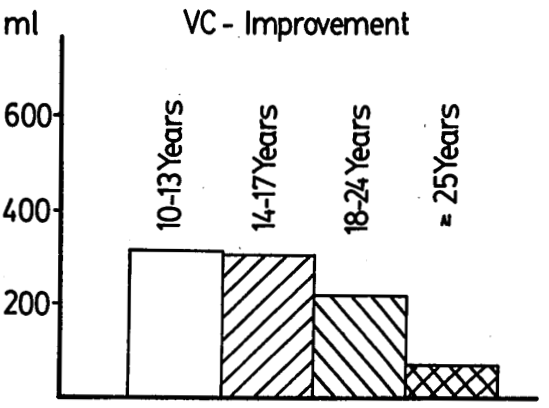

Fig 10. Increases in vital capacity in milliliters after a repeat course of inpatient treatment.

physical training program lasting several weeks. In both cases, increases in cardiopulmonary performance are found, but Bjure et al[1] and Götze[5] were not able to show increases in VC after several weeks of physical training. In view of the fact that in scoliosis patients the work of the right side of the heart increases as VC becomes increasingly impaired,[14] a course of in-patient treatment by the Schroth method can be expected to be particularly beneficial to scoliosis patients with cardiac risk.

With regard to increases in chest expansion, no appreciable differences were found between patients treated for the first time and patients receiving repeat treatment. It was merely noted that there was a general tendency toward greater increases in the waist values than in the armpit and chest values. Altogether, the average absolute values appear to be relatively small; the high level of significance can, however, be explained by the fact that increases were found in almost all cases and that in a large number of the patients they amounted to more than 30% of the baseline values. It must also be emphasized that most of the increases in chest expansion determined here were still significant despite the measurement error of 0.5 cm. Thus, in the entire region of the thorax, increases in chest expansion of more than 1 cm can be expected even in adult scoliosis patients with a rigid thorax.

Because this was not a long-term study, further follow-up of the angle of curvature was not possible. According to a currently unpublished study conducted at our hospital, a decrease in curvature can be expected as a result of a course of in-patient physiotherapy. This study also showed that, in patients with an average Cobb angle exceeding 30° and an average follow-up period of 31.5 months, progression is only to be expected in 16.1% of the cases. It is possible that the increase in VC can also be explained by an increase in intrathoracic volume because of the reduction in curvature. An additional factor is, of course, chest expansion as an index of the degree of rib mobilization achieved. However, on account of the lack of correlation between increase in VC and increase in chest expansion, no definitive conclusions can be drawn here.

CONCLUSION

The physiotherapy program as developed by Schroth can be regarded as highly effective for the prevention or treatment of secondary functional impairment, particularly with respect to the restrictive ventilatory disorder. It has also already been shown to have a beneficial effect on scoliosis related pain.[23] The question of whether the rehabilitation program described is able to influence curve progression will have to be answered by further studies.

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Address reprint requests to

Hans Rudolf Weiss, MD
Katharina-Schroth-Klinik
Zentrum für konservative Skoliosebehandlung
Leinenbornerweg 42-44
D-6553 Sobernheim
Germany

Accepted for publication August 7, 1990.