

**EFFECTS OF REHABILITATION BASED ON ENDURANCE TRAINING
IN ADOLESCENT GIRLS WITH SURGICALLY TREATED SCOLIOSIS**

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Abstract. The aim of the study was to investigate whether appropriate rehabilitation program in the postoperative period can further improve pulmonary function and increase physical performance in patients with idiopathic scoliosis. The study group consisted of 16 adolescent girls in average 2.3 years after surgical treatment of scoliosis. Patients participated in a 4-week, intensive rehabilitation program. Before the rehabilitation program (Term I) and directly after completing it (Term II) patients performed a spiroergometry with intensity increasing up to the ventilatory threshold and a resting spirometry to assess their physical performance. Additionally, patients' maximal oxygen uptake (VO₂max) was determined indirectly. The results of the exercise test performed at the beginning of the study were used to select individual loads for the endurance training. The workload at which the ventilatory threshold was reached and the value of VO₂max were significantly higher during the ergometry at Term II, which indicates that patients' physical performance improved during the rehabilitation program. Ventilatory and circulatory parameters did not differ between exercise tests at Term I and II. Similar response of the cardiopulmonary system to submaximal exercise at greater work load proves increased physical performance. Vital capacity was similar at Term I and II. Maximal voluntary ventilation increased significantly following the rehabilitation program, but was still lower than the predicted value. Rehabilitation training in girls after surgical treatment of scoliosis caused an important increase in the physical performance capacity, which most probably was the result of the endurance training of individually selected intensity.
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Key words: Scoliosis - Endurance training - Physical performance capacity

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Introduction

Idiopathic scoliosis is a well-known, common orthopedic disease of the developmental period. Population-based studies revealed that about 15 percent of children and adolescents have a lateral thoracic spinal curvature [7,22]. Scoliosis is more common in girls, and its course is mild in the majority of cases [5,8]. The management of scoliosis is based on rehabilitation, and results in an improvement of the cardiopulmonary function, increase in the vital capacity, and decrease of the back pain. In patients with thoracic curvature exceeding 50° and tending to progress surgical treatment is recommended. Operation in subjects with moderate scoliosis usually leads to a satisfactory correction of the silhouette and increase in the pulmonary function.

However, it has been observed in several studies [13,16,21] that despite the improvement following surgical treatment, vital capacity in patients with scoliosis remains lower than in healthy subjects. Pehrsson *et al.* [16] examined adults 25 years after surgical correction of scoliosis and found that their vital capacity did improve, but did not reach the predicted value.

In the present study we addressed the issue of whether appropriate rehabilitation in the postoperative period can further improve pulmonary function and increase physical performance in patients with idiopathic scoliosis.

Materials and Methods

Table 1

Anthropometric characteristics of the patients

	Age (years)	Body mass (kg)	Height (cm)	Years after operation
x	16.6	54.1	166.5	2.3
SD	1.50	6.61	7.41	0.71
Min	14.0	41.0	154.0	1.0
Max	20.0	67.0	179.0	3.0

Body mass of patients before and after the rehabilitation program was unchanged

The study group consisted of 16 adolescent girls, in average 2.3 years after surgical treatment of right-sided, thoracic idiopathic scoliosis. Patients were



operated using the method of Cotrel-Dubouset. The mean achieved correction was 50%. The degree of scoliosis after the operation was measured by the method of Cobb and in average was equal to 30°. The anthropometric characteristics of the study population are shown in Table 1.

Patients participated in a 4-week, intensive rehabilitation program. Before the rehabilitation program (Term I) and directly after completing it (Term II) patients performed an exercise test with a computer analysis of the ventilatory expired gas, and a spirometry to assess their physical performance.

The exercise test was performed on a cycle ergometer (Ergo Metrics 900, Ergoline, Germany). The initial load was 25 W; it was increased by 25 W every 3 min until the ventilatory threshold was achieved. The ventilatory threshold was determined based on the continuous analysis of oxygen consumption and carbon dioxide exhalation (CardiO₂ computer system, Medical Graphics Corporation, USA). The results of the exercise test performed at the beginning of the study were used to select individual training loads.

The resting spirometry was performed with a spirometer (PNEUMO PC, RS 2000, ABC Limited Company, Poland). The following parameters were assessed: vital capacity (VC), vital capacity as a percentage of the predicted value (VC%pred.), maximal voluntary ventilation (MVV), maximal voluntary ventilation as a percentage of the predicted value (MVV%pred.), forced expiratory volume in the first second as a percentage of forced vital capacity (FEV_{1%}), FEV_{1%} as a percentage of the predicted value (%pred. FEV_{1%}).

Additionally, the maximal oxygen uptake (VO₂max) was determined indirectly with the Astrand – Ryhming nomogram, and the value of the PWC₁₃₀ test (Physical Working Capacity at 130) was calculated.

The rehabilitation training program consisted of:

- 40-min bicycle ergometer training session 3 times a week. Each session consisted of 5 min of warm-up, 30 min of pedaling with the load at which ventilatory threshold was reached during the first exercise test, and 5 min of cool-down (pedaling without load),
- calisthenics, exercises increasing the respiratory and abdominal muscle strength, exercises improving the posture and breathing exercises – 3 times a week,
- 45-min free swimming in a pool once a week.

Despite the normal distribution of the data, the differences between the two study groups were assessed with the Wilcoxon's test because of the small number of patients enrolled. With the exception of two parameters, the coefficient of variation was low ($V_x < 35\%$). Thus, the arithmetic mean adequately characterized the central tendency.



Results

Table 2

Mean values of cardiopulmonary parameters during exercise of intensity of the ventilatory threshold, the maximal oxygen uptake, and the results of the PWC₁₃₀ test

Parameters	Term I		Term II		Wilcoxon's test
	x	SD	x	SD	
Load (W)	76.25	10.402	90.06	21.953	0.006**
Heart rate (bpm)	158.94	13.097	158.13	13.233	0.887
Minute ventilation (l min ⁻¹)	30.59	9.631	30.55	11.320	1.000
Tidal volume (ml)	1086.88	293.796	1070.33	300.944	0.733
Breathing frequency (breath min ⁻¹)	29.75	4.946	29.67	4.435	0.362
VO ₂ max (ml kg ⁻¹ min ⁻¹)	37.85	4.465	42.14	5.025	0.001**
PWC ₁₃₀ (W)	54.25	21.070	58.87	15.464	0.272

**P<0.01

The data from exercise tests, the maximal oxygen uptake and the results of the PWC₁₃₀ tests and are shown in Table 2. The workload at which the ventilatory threshold was reached was significantly higher during the ergometry performed after the 4-week rehabilitation training. The maximal heart rate was similar during both exercise tests. These results show an improved adaptation of the circulatory system to exercise (equal increase in the heart rate in response to greater work load). Similarly, the parameters describing the ventilatory responses to exercise, such as min ventilation, tidal volume and breathing frequency did not differ between both tests, indicating improved adaptation of the respiratory system to exercise. Similar response of the cardiopulmonary system to submaximal exercise at greater work load proves that exercise tolerance increased following the



rehabilitation program. Significantly higher values of the maximal oxygen uptake, and distinctly (although not significantly) improved results of the PWC₁₃₀ test further confirm enhanced exercise tolerance after 4-week training in adolescent girls with scoliosis.

Table 3

Mean values of the spirometric parameters

Parameters	Term I		Term II		Wilcoxon's test
	x	SD	x	SD	
VC (l)	3.02	0.480	3.05	0.439	0.346
VC%pred. (%)	81.75	12.731	82.63	11.419	0.239
FEV _{1%} (%)	92.43	5.285	92.18	5.002	0.446
%pred. FEV _{1%} (%)	108.22	6.180	108.27	5.781	0.446
MVV (l)	80.57	15.348	87.60	13.876	0.010*
MVV%pred. (%)	64.69	14.244	70.54	13.201	0.009**

**P<0.01; *P<0.05

The spirometric data are presented in Table 3. Vital capacity in girls with scoliosis in each case was lower than the predicted value, and was similar in both terms. This finding indicates that rehabilitation training had no influence on this parameter. Forced expiratory volume in the first second as a percentage of forced vital capacity was similar in both terms. However, the values of FEV_{1%} were within the normal range or even higher. Decreased vital capacity and normal FEV_{1%} show restrictive changes in the respiratory system in girls with scoliosis.

Maximal voluntary ventilation was significantly increased following the 4-week rehabilitation training, which shows improved respiratory muscle strength. Increase in the respiratory muscle strength causes exercises of greater intensity can be tolerated without an effort dyspnea associated with respiratory muscle fatigue, and thus leads to an increase in the exercise tolerance.

Discussion

The positive influence of surgical correction of scoliosis on the functioning of the circulatory and respiratory systems is controversial. It is generally accepted that operation prevents further decline in the cardiopulmonary function. Some authors



observed increased ability to perform exercise after surgical treatment of scoliosis [4,9] or improvement in the functioning of the circulatory and respiratory systems [1,2]. In contrast, Shneerson and Edgar [17] found no significant changes in the physiologic parameters after spinal fusion in adolescents with scoliosis. Maximal oxygen uptake, a measure of exercise capacity, remained at the same level before and after the operation of scoliosis. Similarly, Wierusz-Kozłowska *et al.* [19,20] found no considerable improvement in the respiratory function after surgical treatment of scoliosis, especially in patients with considerable lateral spinal curvature after the operation.

The management of patients with low degree of spinal curvature involves a variety of rehabilitation exercises, including exercises aimed at improving the posture and calisthenics. If applied for a longer period, these exercises decrease the asymmetry of the body and improve the cardiopulmonary function. The results of our study strongly suggest that rehabilitation training based on endurance exercises should be continued after surgical treatment of scoliosis. Surgical intervention does not enable complete reconstruction of the physiologic spinal curves. In our study population, the mean scoliotic curvature after the spinal fusion was 30° . Therefore, our patients still had a moderate scoliosis and required appropriate rehabilitation. While the treatment of scoliosis with physical exercises is not effective, it is possible to improve physical performance of patients with spinal lateral curvature by adequate physical activity, such as endurance training.

It has been found in many studies that patients with scoliosis have decreased exercise capacity [14,18]. Factors contributing to the low physical capacity in adolescents with moderate scoliosis are hardly recognized. Some authors took note of the decreased physical activity of these patients [12,15]. Low physical activity often results from wearing a brace. The reason for decreased physical activity of subjects after the surgical treatment can be spinal arthrodesis. Despite the lack of reliable premises that physical activity accelerates the progression of scoliosis, children with spinal curvatures are usually exempted from physical education classes.

According to Hopf *et al.* [10], the physical activity of children with scoliotic curves below 20° should not be restricted. Subjects with thoracic curvature 21° - 40° should only avoid exercises associated with axial strain in the spine. One year after the surgical treatment of scoliosis patients should return to their normal physical activity, with the exception of contact sports, jumping, etc. A consultation concerning the type of discipline and acceptable intensity of training is necessary before patients after spinal fusion go in for sport.



A favorable influence of physical activity on the physical performance and metabolic processes has been observed both in healthy individuals and in patients with various diseases. It has been demonstrated that rehabilitation training can improve ventilatory parameters, and enhance physical capacity in subjects with scoliosis [6,11,23]. Rehabilitation programs for patients with scoliosis based on exercises engaging the whole body are more effective than programs including exclusively breathing exercises. Such exercises improve the function of the respiratory system, but in contrast to exercises involving large muscle groups, they do not affect the circulation. In addition, systematic endurance training causes adaptive changes at the cellular level that enable more efficient utilization of the supplied oxygen. It has been demonstrated [3] that aerobic training in girls with scoliosis has favorable results.

An appropriate selection of the intensity and duration of training session is essential to avoid strains. On the other hand, too low training load lengthens the rehabilitation process.

Conclusion – rehabilitation of patients with scoliosis should be continued after spinal fusion. In our study, rehabilitation training in girls after surgical treatment of scoliosis caused an important increase in the physical performance capacity. The favorable effects of the rehabilitation program most probably resulted from the endurance training of individually selected intensity.

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