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THE EFFECT OF PHYSICAL TRAINING IN GIRLS WITH IDIOPATHIC SCOLIOSIS

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As known, a lateral curvature of the thoracic spine impairs pulmonary function of the patient (Rieder 1881, Chapman, Dill & Graybiel 1939, Bergofsky, Turino & Fishman 1959, Mankin, Graham & Schak 1964, Fishman 1965, Cotrel 1965). Working capacity and life expectancy were found to be decreased in a recent long-term follow-up of non-treated scoliosis (Nachemson 1968). These patients were followed for 15-40 years and it was found that the pulmonary insufficiency caused by the scoliosis accounted for 100 per cent overmortality compared with normal subjects. For subjects with severe thoracic curves this overmortality was about 400 per cent.

In the present investigation of a selected group of scoliotic girls ventilatory function and physical fitness were studied in an attempt to find out whether a physical training program could increase the physical performance and thus form a basis for future advice to these severely handicapped patients.

MATERIAL

The material consisted of 11 girls, aged 16-27 years, with idiopathic scoliosis. The age, the localization of the scoliosis, and the degree of the curve measured according to Cobb (1948) are given in Table 1. All the girls had reached skeletal maturity, as judged from the iliac apophysis sign (Risser 1964). Some of the patients had been previously operated upon. At least 2 years had elapsed between the spinal fusion and this training period. Heart catheterization had been performed 1-3 years previously in cases Nos. 3, 5, 6, 10, and 11. All had normal pressures and flow in the pulmonary circulation at rest and during moderate exercise, with the exception of No. 11, who had moderate pulmonary hypertension during light work. (Mean pulmonary pressure: 26 mm Hg, cardiac output 9.9 l/min, oxygen uptake 0.62 l/min.)

Table 1.

Pat. no.	Age (yrs)	Height (cm)	Weight (kg)	Type of curve	Degree (Cobb) of prim. curve	Previous therapy (none had had treatment for the preceding 18 months)
1	18	131	40	idiopathic. mid. thor.	100°	Milwaukee brace, Harrington rod + fusion 3 yrs prev., part. res. of scapula and ribs 2 yrs prev.
2	20.5	163	56	idiopathic. mid. thor.	120°	Plaster corsets, Harrington rod + fusion 3 yrs. prev. part. res. of scapula 2 yrs prev.
3	25	150	43	idiopathic. mid. thor.	150°	Plaster corsets, Milwaukee brace. Rib. resect. 3 yrs prev.
4	17	163	46	idiopathic. thoracolumbar	35°	Milwaukee brace
5	20.5	155	47	idiopathic. thoracolumbar	95°	Milwaukee brace, Harrington rod + fusion 3 yrs prev. Rib. resect. 2 yrs prev.
6	25	152	42	idiopathic. mid. thor.	110°	Milwaukee brace, Harrington rod + fusion 3 yrs prev.
7	16.5	162	56	idiopathic. mid. thor.	35°	None
8	17	165	52	idiopathic. mid. thor.	30°	None
9	27	156	53	idiopathic. mid. thor.	90°	Plaster corsets. Conventional fusion 3 yrs prev.
10	23	156	46	idiopathic. thoracolumbar	120°	Plaster corsets, Milwaukee brace. Harrington rod + fusion 2 yrs prev.
11	22.5	154	33	idiopathic. mid. thor.	115°	Plaster corsets

METHODS AND PROCEDURE

The dynamic lung volumes (vital capacity and forced expiratory volume in 1 sec) were determined and normal values were predicted for equations published by Berglund, Birath, Bjure, Grimby, Kjellmer, Sandqvist & Söderholm (1963).

Plasma volumes were measured with I^{131} human serum albumin and the total blood volume calculated using the hematocrit of venous blood.

Resting electrocardiograms were recorded with standard extremity leads, unipolar extremity leads, and five chest (CR) leads. The patients were then exercised in the sitting position on an electrically braked bicycle ergometer (Elema, Stockholm) with the indifferent electrode on the forehead. Step-wise-increasing work loads were used up to the "maximum". The expired air was then collected in Douglas bags for the determination of "maximal" oxygen uptake. The exercise time on each submaximal work load was 6 minutes.

All patients had earlier experience in exercise tests. Lactic acid was determined one and five minutes after "maximal" exercise in prewarmed fingertip blood using the enzymatic method (Lundholm, Mohme-Lundholm & Vamos 1963).

After about three months of physical training the same studies were repeated.

The program aimed at training the patients regularly 3 times weekly for 3 months. The average attendance was 24 times (14-35).

The sessions consisted of:

- A. Warming-up exercises: walking, running, jogging, deep-breathing exercises for 3 minutes.
- B. Circle training: This was devised to activate large muscle groups. The program consisted of six different exercises which were individually programmed according to the capacity of the patient with about 3 minutes' work, repeated 3 times, with a rest interval of 3 minutes. The types of exercises used were:
 1. jumping up and down on a low seat (20 cm)
 2. throwing a medicine ball (2.5 kg) against a wall
 3. stationary running while keeping the hands on the wall
 4. combined arm-throwing and knee-bending in the supine position
 5. skipping
 6. "Indian" jump.

The program was individualized by first testing the maximal number of each exercise that could be performed in one minute. During the actual training half the number of each type of exercise was performed in a sequence. The time consumed for this and the pulse rate at completion was measured once weekly.

- C. Bicycling: The patient was trained for 2-4 minute periods on a work load which gave a heart rate of 160-180 beats/min, except in case No. 11 who had pulmonary hypertension. This patient was trained only at intensities which gave heart rates below 140.

RESULTS AND DISCUSSION

Table 2 gives the results of spirometry and the maximal exercise test before and after the training period. The heart rate at a submaximal

Table 2. Results from dynamic spirometry and maximal exercise test.

Patient no.	Vital capacity (BTPS)		Forced expiratory volume in one sec. (BTPS)		Blood volume lit	Oxygen uptake ml/kg $\times$ min	Maximal exercise			Tidal volume lit	Arterial lactate conc. mM/l
	lit % pred.	lit % pred.	lit % pred.	lit % pred.			Heart rate	Ventilation lit/min	Respir. rate		
1 b	1.1	40	0.9	36	-	-	173	-	-	-	-
a	1.2	44	1.0	41	-	-	-	-	-	-	3.9
2 b	2.4	51	2.2	51	3.8	27.3	198	52.3	46	1137	8.3
a	2.3	49	2.2	51	5.1	45.4	197	88.9	53	1677	7.6
3 b	2.2	53	1.8	48	4.4	29.1	165	45.9	46	998	3.0
a	2.1	50	1.9	52	-	30.5	168	43.6	46	948	2.0
4 b	3.6	89	3.5	97	4.2	32.5	194	54.3	38	1429	7.6
a	3.6	89	3.4	94	-	33.8	197	60.0	-	-	5.6
5 b	2.4	61	2.2	63	3.1	35.0	196	66.5	56	1188	6.8
a	2.6	67	2.3	66	3.4	35.4	198	61.4	56	1096	7.4
6 b	1.9	44	1.5	42	3.2	27.7	175	38.3	38	1008	4.3
a	1.9	44	1.5	42	3.0	34.0	187	55.6	49	1135	7.1
7 b	3.4	86	3.4	97	-	34.8*	206	-	-	-	4.7
a	3.4	86	3.4	97	4.7	40.9	206	65.7	29	2266	5.4
8 b	3.5	84	2.5	68	2.6	27.3	185	38.1	34	1121	3.8
a	3.6	87	2.9	76	-	37.5	192	65.5	39	1679	8.2
9 b	2.1	50	1.8	50	3.6	27.6	168	54.0	-	-	5.4
a	2.2	53	1.9	53	4.7	34.7	180	65.1	61	1067	6.1
10 b	2.5	59	2.2	59	3.0	29.8	192	51.9	40	1298	6.3
a	2.4	56	2.2	59	-	35.2	192	59.8	46	1300	6.6
11 b	1.5	41	1.4	43	4.6	-	155	-	-	-	-
a	1.3	35	1.1	33	-	29.1	148	29.9	52	575	4.3

b: before training.

a: after training.

* Predicted according to I. Astrand (1960).

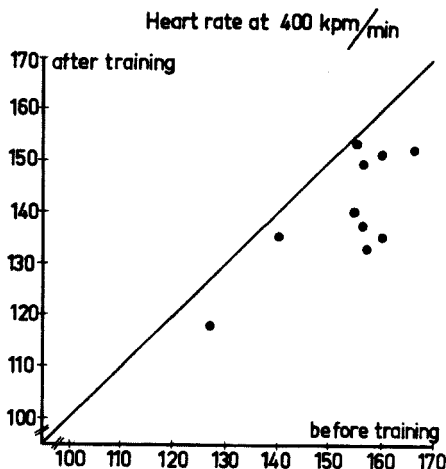


Figure 1. The heart rate at 400 kpm/min, before and after training, in 10 patients (No. 1 could not manage this work load before training). The identity line is drawn.

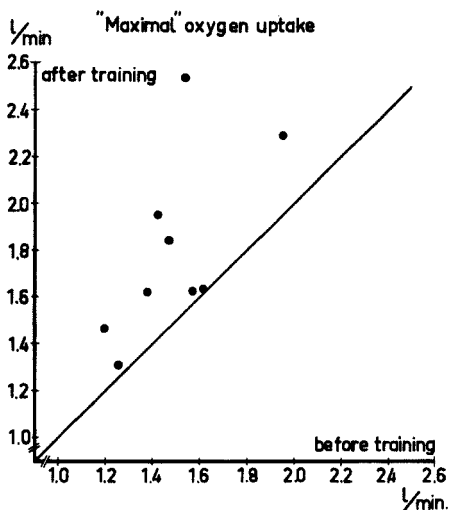


Figure 2. The "maximal" oxygen uptake before and after training in 9 patients. The identity line is drawn.

work load (400 kpm/min) and the maximal oxygen uptake before the training are given in Figures 1 and 2, respectively.

Normal values for vital capacity (VC) and forced expiratory volume in one second ($FEV_{1.0}$) were recalculated after allowance for the reduced height due to the scoliosis. The procedure and the importance of such a correction in about 70 cases with scoliosis has been reported separately (Bjure, Grimby & Nachemson 1968). In the present study the actual values are given as percentages of predicted corrected val-

ues. All patients had lower lung volumes than predicted; on an average, 60 per cent of predicted VC and 59 per cent of predicted $FEV_{1.0}$. There were no signs of airway obstruction. Also in this material large curvatures resulted in low vital capacity which agrees with the findings of, among others, Mankin et al. (1964) and Cotrel (1965).

No abnormal ECG-changes were recorded at rest, during, or after exercise. Before training all patients had high heart rates at sub-maximal exercise (average: 153 beats/min at 400 kpm/min) and low "maximal" oxygen uptake (average: 30 ml/kg $\times$ min). In a group of females 20–29 years of age, I. Astrand (1960) reported a mean value of 40 ml/kg $\times$ min. The "maximal" ventilation was in the present group 50 lit/min compared to 70 lit/min in the control group mentioned above. The mean respiratory rate was 43 and the mean tidal volume was 1.2 lit (46 per cent of the vital capacity). The "maximal" heart rate was 187 beats/min, which is identical with the figure reported by I. Astrand (1960).

When discussing the working capacity of scoliotic patients, some factors must be taken into consideration:

- A. The chest deformity which results in reduced vital capacity and increased work of breathing (Bergofsky et al. 1959).
- B. The small lung which can lead to restriction of the pulmonary vascular bed and pulmonary hypertension.
- C. The long-time inactivity, which will result in, *e.g.*, decreased muscular strength, small circulatory dimensions, and inadequate regulation of the circulation during muscular exercise.

The results obtained in this group of patients seem to indicate that the ventilatory function is the main limiting factor of physical performance in only a few cases (*e.g.* patients Nos. 3 and 11), and no correlation could be found between "maximal" oxygen uptake and the reduction in vital capacity. This assumption was further supported by studying the effect of training on the "maximal" oxygen uptake. Pulmonary hypertension was observed only in No. 11 during moderate exercise with a normal cardiac output. Thus, in most of these young patients a lack of training is an important factor leading to the reduced physical performance.

Training had no effect on VC and $FEV_{1.0}$. As shown in Figure 1 the heart rate at 400 kpm/min decreased in all patients (on an average 13 beats/min). Figure 2 shows that the "maximal" oxygen uptake increased in nine studied patients (average 22 per cent) but with negli-

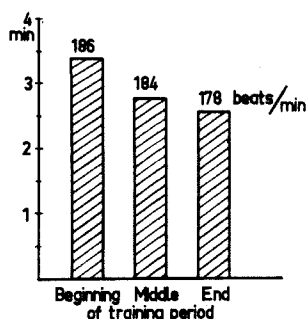


Figure 3. Time required for a series of exercises in the circle training program (see text) at the beginning, middle, and end of the 3-month training period in patient No. 10. The numbers above the bars are the heart rates at the end of each exercise session.

gible change in three of the patients (Nos. 3, 4, and 5). The effect of the training may both be a more adequate regulation of the peripheral blood flow, resulting in an increased arteriovenous oxygen difference, and an increased stroke volume (Carlsten & Grimby 1966). In the patients in whom there was a substantial increase in the "maximal" oxygen uptake, the ventilation also increased which resulted in an identical ventilation per liter oxygen (35 lit/lit O_2) before and after training. On the average, the tidal volume during "maximal work after training was 54 per cent of the vital capacity. In two cases (Nos. 2 and 7) values as high as 75 and 67 per cent, respectively, were noted.

The purpose of the physical training was mainly to train the circulatory system. It consisted of repeated periods of strenuous exercises lasting 3–4 minutes. This time is sufficient to produce high values for oxygen uptake (Åstrand & Saltin 1961, Karlsson, Åstrand & Ekblom 1967). During the "training" period the time for a certain number of exercises decreased. An example of this is shown in Figure 3, together with the heart rates at the end of the exercises.

Of the eleven patients studied, five had previous spinal fusions. Eriksson & Foss-Hauge (1963) have demonstrated that a spinal fusion will not affect the vital capacity in such patients.

The present material is too small to allow definite conclusions on the different effects of physical training in patients with mild, moderate, or severe scoliosis. There is, however, a trend. Some patients who stopped working spontaneously at a relatively low heart rate (*e.g.* Nos. 3 and 11) did so because of a ventilatory limitation of their physical performance, which was not improved with training. These patients are found among those with the largest curvatures. Maximal exercise tests, including ventilatory measurements, can be valuable in selecting suitable patients for a training program.

The low working capacity, noted from the start, is probably common

in scoliotic patients. As mentioned above, this can be accounted for by different somatic reasons. It is also a common clinical observation that these patients suffer mentally from their deformity. Therefore, they seldom take part in physical activities. The low physical performance limits their vocational ability to very light work (Nachemson 1968). Continuous physical training, in selected patients, may in some measure be of value, leading to higher achievements in their daily work and leisure time.

SUMMARY

Eleven scoliotic girls aged 16–27 years were studied with dynamic spirometry and exercise tests, including determination of maximal oxygen uptake before and after a 3-month training period.

Most patients had low vital capacity (60 per cent of predicted) and maximal oxygen uptake ($30 \text{ ml/kg} \times \text{min}$).

In two patients the ventilatory function and in one patient moderate pulmonary hypertension were considered important as limiting factors of their physical performance.

After training the heart rate at submaximal work load was, on the average, 13 beats per min lower than before training, and the maximal oxygen uptake was increased by 22 per cent. Thus, in most of these patients the lack of training seems to be an important factor reducing their physical fitness. Some of the patients with the largest curvatures had a ventilatory limitation of their physical fitness and did not improve with training.

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