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THE EFFECT OF BREATHING EXERCISES ON THE VITAL CAPACITY IN PATIENTS WITH SCOLIOSIS TREATED BY SURGICAL CORRECTION WITH THE HARRINGTON TECHNIQUE

M. Lindh, R.P.T. and A. Nachemson, M.D.

From the Department of Orthopaedic Surgery, University of Gothenburg, Sweden

ABSTRACT. The changes in vital capacity in patients surgically corrected for scoliosis were measured at regular intervals in 28 patients over a 6 months period and in 24 of them for 1 year following the operative procedure. The correction caused an average increase in VC of 0.21 litres, which is proportional to the gain in height resulting from the operation itself. Attempt was made in 14 patients to affect the vital capacity value by breathing exercises during a postoperative time of 6 weeks. Compared with those 14 patients that did not receive such exercises these patients quicker regained or increased their preoperative value. The average observed increase in VC at 6 months was also higher in the former group, 0.26 litres versus 0.14 litres in those 14 that did not receive any breathing exercises.

This study was performed to evaluate the changes in vital capacity (VC) occurring after surgical correction of patients with scoliosis using Harrington rods (14) and to find out whether pre- and postoperatively instituted breathing exercises might be of any value for increasing this subdivision of the lung volume.

A severe deformity of the spine often leads to cardio-pulmonary symptoms (1, 4, 5, 6, 15, 16, 19). In the adolescent patients these symptoms are seldom significant, however, even with a severe scoliosis, although reduction of the lung volume is a fact already at an early stage (4, 7, 15, 19).

MATERIAL AND METHODS

28 patients aged 11 to 20 years had surgical correction of the curvature performed with Harrington distraction rods, followed by spine fusion using autogenous iliac bone. The corrections were made in two stages with an interval of 2 weeks in all but 4 cases (no. 1, 6, 10 and 12) where correction and spine fusion were carried out in one operation. After the fusion procedure the period of absolute recumbency, without external support, was 6 weeks, whereafter the patients were allowed out of bed with a well fitted Milwaukee brace. With this brace they could leave the hospital within a week. The relevant clinical data on these patients are seen in Table I.

The mean correction of the spinal curve at discharge from hospital was 35° or 48.5%. At the 6 months follow-up the average loss of correction was 2°.

Pulmonary function tests consisted of measurements of the Vital Capacity, and Forced Expiratory Volume in one second.

A portable dry spirometer with an electric recorder for dynamic tests (Vitalograph, Kifa) was used.

3 static and 3 dynamic tests were performed in the sitting as well as the supine positions. The largest of the vital capacity determinations in each position was used for comparison.

The mean difference was 0.08 litres and most often the highest value was recorded in the sitting position, contrary to Gucker (12) who made the opposite findings.

The largest VC determination in the supine position was utilized in this study as the postoperative VC had to be obtained in recumbency. This determination also was used to calculate the percentage of the predicted vital capacity before treatment.

From the best of the three dynamic curves on the Vitalograph recorder FEV 1.0 and FEV/VC% were recorded.

The normal vital capacity value for young subjects of the same height, sex and age were used as predicted values (2). No attempt has been made to calculate the corrected predicted vital capacity (according to Bjure et al. (3)) before or after correction, since the data were utilized for intrasubject comparison only.

To find out whether breathing exercises might be of any value in increasing the vital capacity after surgical correction the patients were divided into two groups:

Group A (patients no. 1–14) who performed breathing exercises daily during the time of recumbency. Group B (patients no. 15–28) who were only helped in coughing up secretion immediately after the operation.

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Table I

Pat. no.	Sex	Age	Type of curve	Main localization	Before surg. correction: Height Stand.	Before surg. correction: Height Sitting	Before surg. correction: Degree Stand.	After surg. correction: Height Stand.	After surg. correction: Height Sitting	After surg. correction: Degree Stand.	6 months after surg. correction: Height Stand.	6 months after surg. correction: Height Sitting	6 months after surg. correction: Degree Stand.
1	♀	16	Idiopathic	Thoracic	169	86.5	50	171	89.5	30	171	89	35
2	♀	17	Idiopathic	Double primary	161	85	80; 60	164.5	88	40; 35	164	87.5	45; 35
3	♀	13	Idiopathic	Thoracic	159	82	55	162	84.5	20	163	85	22
4	♀	12	Idiopathic	Thoracic	153.5	78	55	157	81	25	158	81.5	30
5	♀	12	Idiopathic	Double primary	161.5	82	45; 60	165	87	30; 28	165	87	30; 30
6	♀	11	Congenital	Thoracic	146	74	90	152	78.5	50	154.5	79	60
7	♀	19	Idiopathic	Thoracic	168.5	86	50	171	89.5	30	170	88.5	30
8	♀	14.5	Idiopathic	Thoracic	177.5	91	65	180	94	20	181.5	94.5	20
9	♀	15	Idiopathic	Thoracic	162	85	90	168	87	50	168	86	50
10	♀	15.5	Idiopathic	Thoracic	175	95.5	60	177	92.5	30	176	92	30
11	♀	14.5	Idiopathic	Thoracic	163.5	86	55	165	88	25	167	89	25
12	♂	17	Polio-myelitic	Thoracic	173.5	86	115	179.5	90.5	75	180	91	80
13	♀	17.5	Idiopathic	Thoraco-lumbar	164.5	84.5	75	168.5	89.5	40	168	88.5	40
14	♀	11.5	Idiopathic	Thoracic	148.5	79	75	151	81.5	32	153	82	30
15	♀	13	Paralytic	Thoraco-lumbar	—	76	85	—	81	20	—	81	20
16	♀	11	Idiopathic	Thoracic	156.5	86	50	158.5	88	20	160	89	33
17	♀	20	Idiopathic	Thoraco-lumbar	156.5	84	95	162	89.5	45	162	89.5	47
18	♀	19	Idiopathic	Thoracic	161.5	77.5	125	165.5	81.5	90	165	81	90
19	♀	15	Idiopathic	Thoracic	167.5	77	120	175.5	86	85	175.5	86	85
20	♀	14	Idiopathic	Thoracic	158.5	78	85	163	83	55	162.5	83	45
21	♀	13.5	Idiopathic	Thoracic	155	80	65	157.5	81.5	20	158	82.5	25
22	♀	16	Idiopathic	Thoracic	150.5	77.5	90	156.5	82.5	55	156	82	60
23	♀	16	Idiopathic	Thoracic	169	90.5	55	171	91.5	17	171	91.5	17
24	♀	14	Congenital	Thoraco-lumbar	153.5	75.5	100	159.5	81	45	160	81.5	45
25	♀	16	Idiopathic	Thoracic	168	87.5	70	171	91.5	45	170.5	91	45
26	♀	16.5	Idiopathic	Thoracic	166.5	85.5	60	170.5	89	25	170.5	89.5	28
27	♀	17	Idiopathic	Thoracic	155.5	80.5	75	161	86	30	161	86	30
28	♂	18	Poliomyelitic	Thoracic	159	82	95	165.5	87	60	165	87.5	60

The patients in the Groups A and B were those operated upon during two following 6 months periods at the department, but were otherwise unselected.

Breathing program

1. Deep breathing exercises, (*a*) diaphragmatic breathing, (*b*) upper costal breathing, (*c*) lower costal breathing.
2. Resistance added to the lower costal breathing by (*a*) manual resistance, (*b*) strap round the lower thorax.
3. Expansion exercises for the thorax using strap resistance in an attempt to get segmental expansion of the greatest deformity.
4. Blowing up a balloon, holding 2–4 litres. These exercises were similar to repeated vital capacity determinations.

RESULTS

Group A

For Group A the mean value of vital capacity was 70% of predicted normal (uncorrected). FEV 1.0 was reduced to the same extent but in proportion to vital capacity it was normal.

The vital capacity in per cent predicted and in absolute value in litre is shown in Table II A. The repeated determinations of vital capacity during the postoperative period of recumbency are expressed in litre. Determinations were also made 3 and 6 months postoperatively.

After the period of recumbency the patients in Group A showed an average increase in vital capacity of 12% (−3.7% to +55%) expressed as a percentage of the pretreatment absolute value. The mean values after 3 and 6 months were almost identical (Fig. 1).

Gain and loss of vital capacity at the different occasions expressed in per cent of the individual preoperative absolute value for each pa-

Table II A and B

Pat. no.	Localization of main curve	Degree Stand.	Height Stand.	% VC pred.	VC litre preop. 1st op.	VC 3 days postop.	VC preop. 2nd op.	VC 3 days postop.	Weeks postop. 2	3	4	5	6	After 3 months	After 6 months
A															
1	Thoracic	50	169	87	—	—	3.38	2.74	3.26	3.33	3.28	3.37	3.45	3.45	3.45
2	Double primary	80; 60	161	67	2.30	1.80	2.20	1.90	2.18	2.30	2.45	2.45	2.55	2.53	2.52
3	Thoracic	55	159	91	3.02	2.55	2.74	2.56	2.86	3.10	3.10	3.10	3.16	3.24	3.24
4	Thoracic	55	153.5	75	2.27	1.50	1.90	1.67	1.81	1.88	1.90	2.17	2.34	2.30	2.32
5	Double primary	45; 60	161.5	70	2.40	2.00	2.53	2.48	2.55	2.55	2.46	2.65	2.63	2.58	2.65
6	Thoracic	90	146	68	—	—	1.80	1.53	1.55	1.68	1.78	1.93	1.92	1.90	1.90
7	Thoracic	50	168.5	90	3.48	3.20	3.30	3.14	2.89	3.00	3.07	3.27	3.35	3.40	3.35
8	Thoracic	65	177.5	70	3.10	2.89	3.00	2.84	3.26	3.35	3.50	3.65	3.63	3.55	3.53
9	Thoracic	90	162	57	2.00	1.94	2.57	2.72	2.93	3.05	3.05	3.05	3.10	2.85	2.85
10	Thoracic	60	175	71	—	—	3.04	2.81	3.20	3.27	3.45	3.63	3.63	3.60	3.56
11	Thoracic	55	163.5	64	2.27	1.18	1.80	1.75	2.19	2.10	2.24	2.38	2.44	2.56	2.58
12	Thoracic	115	173.5	33	—	—	1.60	1.21	1.44	1.45	1.60	1.65	1.63	1.66	1.67
13	Thoraco-lumbar	75	164.5	91	3.30	3.11	3.34	3.19	3.45	3.47	3.60	3.57	3.65	3.60	3.56
14	Thoracic	75	148.5	53	1.50	1.50	1.56	1.63	1.75	1.75	1.86	1.89	1.89	1.90	1.95
B															
15	Thoraco-lumbar	85	—	98	3.03	1.95	2.61	2.37	2.46	2.75	2.78	2.80	2.83	3.05	3.11
16	Thoracic	50	156.5	78	2.48	1.58	2.25	2.07	2.33	2.32	2.26	2.35	2.35	2.50	2.50
17	Thoraco-lumbar	95	156.5	73	2.58	1.96	2.50	2.42	2.64	2.77	2.99	2.96	3.00	3.13	3.05
18	Thoracic	125	161.5	46	1.61	1.55	1.70	1.75	1.75	1.79	1.80	1.80	1.80	1.81	1.80
19	Thoracic	120	167.5	53	2.00	1.21	1.82	1.52	1.80	1.95	2.02	2.05	2.14	2.14	2.16
20	Thoracic	85	158.5	67	2.20	1.75	2.09	2.03	2.09	2.26	2.26	2.39	2.43	2.45	2.45
21	Thoracic	65	155	74	2.25	1.80	2.09	2.00	2.20	2.15	2.20	2.14	2.24	2.33	2.30
22	Thoracic	90	150.5	64	1.85	1.35	1.86	1.50	1.76	1.92	1.94	2.05	2.00	2.00	2.00
23	Thoracic	55	169	84	3.25	2.67	3.22	2.71	2.80	3.10	3.05	3.20	3.20	3.27	3.31
24	Thoraco-lumbar	100	153.5	91	2.75	1.79	2.15	2.12	2.32	2.32	2.56	2.55	2.78	2.66	2.81
25	Thoracic	70	168	90	3.43	2.11	2.95	2.45	2.90	3.01	3.06	3.27	3.33	3.36	3.54
26	Thoracic	60	166.5	72	2.70	2.43	2.75	2.58	2.70	2.75	2.85	2.81	2.86	2.84	2.77
27	Thoracic	75	155.5	88	2.75	0.88	2.55	2.16	2.64	2.80	2.92	2.85	2.93	3.10	3.11
28	Thoracic	95	159	82	3.05	1.25	2.31	1.77	2.00	2.26	2.66	2.85	2.95	2.94	2.99

tient is seen in Table III A. If the preoperative VC in litre is compared with the postoperative value an average increase of 0.26 litres is noted. The operation, however, also resulted in a gain of height ranging from 1–9 cms ($\bar{m} = 3.8$). The increase in predicted VC from this averaged 0.23 litres (Table IV).

Group B

For this group the mean value of vital capacity was 75.5% of the normal. FEV 1.0 was reduced as in Group A and FEV 1.0 as per cent of vital capacity was normal.

After the recumbent period the patients in Group B had a mean increase in vital capacity of 3.4% (−6.6% to +16.2%). The mean values after 3 and 6 months showed a slight further increase (Fig. 1).

Gain and loss of vital capacity expressed in per cent of the individual preoperative absolute value for each patient are seen in Table III B. If the preoperative VC in litre is compared with the postoperative value an average increase of 0.14 litres was noted. In this group the operation resulted in a gain of height ranging from 2–8 cm ($\bar{m} = 4.4$ cm). The increase in predicted VC from this averaged 0.26 litres (Table IV).

DISCUSSION

There are certain difficulties in estimating the value of the results when the small changes in

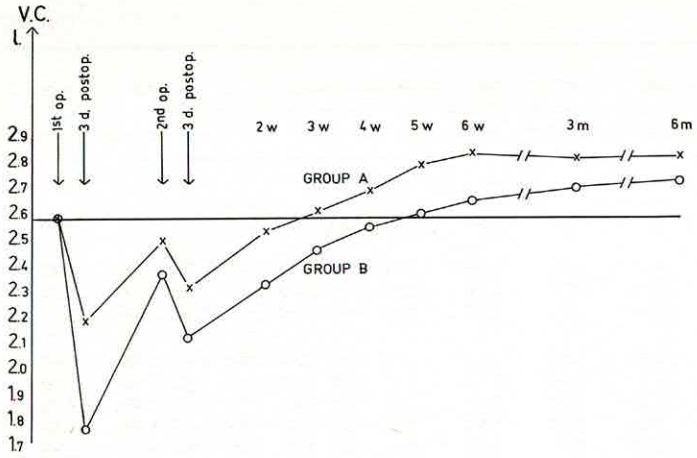

Fig. 1. Changes in VC following surgery for scoliosis. Group A received regular breathing exercises for 8 weeks. Group B received no breathing exercises. Mean values from Table II A and B are drawn. The difference between the two groups is statistically significant.

Table III. *Gain and loss in VC expressed in per cent of preop. absolute values*

Pat. no.	3 days postop.		Preop.		3 days postop.		Weeks postop. 2		3		4		5		6		After 3 months		After 6 months	
	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+
A. *No. 1–14 with breathing exercises*																				
1	—	—	—	—	18.9		3.5		1.5		2.9		0.3		2.0		2.0		2.0	
2	21.7		4.3		17.3		5.2		No change		6.5		6.5		10.8		10.0		9.5	
3	15.5		9.2		15.2		5.3		2.6		2.6		2.6		4.6		7.2		7.2	
4	33.9		16.3		26.0		20.3		17.1		16.3		4.4		1.7		1.3		2.2	
5	16.6			5.4		3.3		6.2		6.2		2.5		10.4		9.5		7.5		10.4
6	—	—	—	—	15.0		13.8		6.6		1.1			7.2		6.6		5.6		5.5
7	8.0		5.1		9.7		16.9		13.7		11.7		6.0		3.7		2.3		3.7	
8	6.7		3.2		8.3			5.1		8.0		12.9		17.7		17.2		14.5		13.8
9	3.0			28.5		35.0		45.5		52.5		52.5		52.5		55.0		42.5		42.5
10	—	—	—	—	7.5			5.2		7.5		13.4		19.4		19.4		18.4		17.1
11	48.0		20.7		22.9		3.5		7.4		1.3			4.8		7.4		12.7		13.6
12	—	—	—	—	24.3		10.0		9.3		No change			3.1		1.8		3.7		4.3
13	5.7			1.2	3.3			4.5		5.1		9.0		8.1		10.6		9.0		7.8
14	No change			4.0		8.6		16.6		16.6		24.0		26.0		26.0		26.5		30.0
Mean values	−15.9		−1.9		−8.6		+0.3		+3.0		+6.4		+10.5		+12		+11.3		+11.6	
B. *No. 15–28 no breathing exercises*																				
15	35.6		13.8		21.7		18.8		9.2		8.2		7.5		6.6		0.7		2.6	
16	36.2		9.2		16.5		6.0		6.4		8.8		5.2		5.2		0.8		0.8	
17	24.0		3.8		6.2			2.3		7.3		12.0		10.8		16.2		21.3		18.0
18	3.7			5.6		8.7		8.7		11.1		11.8		11.8		11.8		12.4		11.8
19	36.5		9.0		24.0		10.0		2.5		1.0			2.5		7.0		7.0		8.0
20	20.4		5.0		7.7		5.0			2.7		2.7		8.6		10.4		11.3		11.3
21	20.0		7.1		11.2		2.2		4.4		2.2		4.8		0.4			3.5		2.2
22	27.0			0.5	18.9		4.8			3.7		4.8		10.8		8.1		8.1		8.1
23	17.8		0.9		16.6		13.8		4.6		6.1		1.5		1.5			0.6		1.8
24	31.2		21.8		22.9		15.6		15.6		6.9		7.2			1.0	3.3			2.1
25	38.4		13.9		28.5		15.4		12.2		10.7		4.6		2.9		2.0			3.2
26	10.0			1.8	4.4		No change			1.8		5.5		4.0		5.9		5.1		2.6
27	68.0		7.2		21.4		4.0			1.8		6.1		3.6		6.5		12.7		13.0
28	59.0		24.2		41.9		34.4		25.9		12.7		6.5		3.2		3.6		1.9	
Mean values	−30.5		−7.7		−16.6		−8.5		−3.7		−0.9		+1.0		+3.4		+5.3		+5.9	

Table IV

Pat. no.	Height increase (cm)	Change in VC. 6 mo postop. lit.	Change in predict. VC due to height increase
Group A			
1	2	+0.07	+0.12
2	3	+0.22	+0.18
3	4	+0.22	+0.23
4	4	+0.05	+0.22
5	3	+0.25	+0.18
6	9	+0.10	+0.45
7	1	−0.13	+0.06
8	4	+0.43	+0.29
9	6	+0.85	+0.36
10	1	+0.52	+0.06
11	3	+0.31	+0.18
12	6	+0.07	+0.53
13	3	+0.26	+0.18
14	4	+0.45	+0.20
	$\bar{m}=3.8$	$\bar{m}=+0.26$	$\bar{m}=+0.23$
Group B			
15	5	+0.08	+0.27
16	3	+0.02	+0.17
17	5	+0.47	+0.28
18	3	+0.19	+0.18
19	8	+0.16	+0.52
20	4	+0.25	+0.23
21	3	+0.05	+0.17
22	5	+0.15	+0.27
23	2	+0.06	+0.12
24	6	+0.06	+0.33
25	3	+0.11	+0.19
26	4	+0.07	+0.25
27	5	+0.36	+0.27
28	6	−0.06	+0.44
	$\bar{m}=4.4$	$\bar{m}=0.14$	$\bar{m}=+0.26$

per cent are based on a test method where the determinations are highly dependent on the patients ability and will to cooperate. As the final results to a great extent are dependent on reliable preoperative tests, these were first performed several times in the sitting position as a training before the supine determinations were made, and these latter were calculated upon. These repetitions were made in an attempt to diminish the source of error caused by lack of training. Each following test consisted of 6 measurements, where the largest determination was used for comparison. Following surgical correction and spinal fusion the vital capacity at first decreases but then gradually tends to revert to its pre-treatment value in litre (Fig. 1).

Expressed in per cent of predicted value there is in Group B a slight decrease after the recumbent period, but this decrease tend to diminish, which can be seen in the follow-up measurements.

It should also be mentioned that 24 of the total 28 patients were remeasured after 1 year without any significant change.

In this series of patients correction of the spinal curve caused a significant increase of vital capacity. Other authors have reported impairments (12, 14) as well as improvements (8, 9, 12, 18) following the spinal fusion. The Milwaukee brace used following the recumbency period did not affect the VC in a negative direction.

As judged from the results obtained in Group A breathing exercises in the postoperative period is of value in quicker restoring the postoperative vital capacity to or above the preoperative value (Fig. 1). The difference between the two groups in gain in absolute value of VC after 6 months is rather small 0.26 litres versus 0.14 litres.

When compared with the postoperative values of VC corrected for height increase (Table IV), there is, however, a significant difference between the two groups.

Vallbona et al. (17) in a similar study of 12 patients with idiopathic scoliosis operated upon by Harrington instrumentation reported a small but unsignificant increase in per cent predicted VC one year following surgery. These authors do not mention any particular postoperative program of breathing exercises, nor did Westgate & Moe (18), who reported in 14 patients with idiopathic scoliosis a slight decrease in VC one year following the Harrington instrumentation procedure. In the lastmentioned series the comparison was made with the values predicted from the preoperative height only.

Cotrel et al. (9) reported improvement of 30 to 40% of preoperative litre values after correction treatment followed by intensive physical therapy for many months.

The action of breathing exercises in this study has only been estimated concerning changes in vital capacity. No attempt has been made to evaluate any other possible effects of such exercises.

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Address for reprints:
Alf Nachemson, M.D., Assoc. prof.
Ortopediska kliniken
Sahlgrenska sjukhuset
413 45 *Göteborg,* Sweden