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Cardiac and respiratory function before and after spinal fusion in adolescent idiopathic scoliosis

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ABSTRACT Ten girls with adolescent idiopathic scoliosis were studied before and 17–23 months after spinal fusion. None had any cardiac or respiratory disease complicating the scoliosis. They underwent a range of resting lung function tests and a progressive exercise test. The mean angle of scoliosis decreased from 65·8 to 27·3 degrees after operation but the only significant physiological benefit detected in this study was a decrease in the submaximal minute ventilation. The physiological benefit of spinal fusion was therefore much less prominent than the anatomical improvement of the spinal curvature.

Although the obvious effect of thoracic scoliosis is an anatomical deformity, it also causes various cardiac and respiratory physiological abnormalities. These include diminished lung volumes (Larmi *et al*, 1955), pulmonary hypertension (Bergofsky *et al*, 1959; Shneerson, 1978a), and diminished maximal oxygen uptake and ventilation during exercise (Shneerson, 1978b). Over half the deaths in a series of 762 scoliotics were from cardiac or respiratory complications (Shneerson *et al*, 1978).

Spinal fusion is an effective method of correcting the anatomical deformity, but there is little information on its cardiorespiratory consequences. If there were any improvement or prevention of deterioration the indications for operation might be widened. In this study 10 patients underwent a range of resting lung function tests and a progressive exercise test before and after spinal fusion. The results have been compared to assess the effect of operation.

Subjects and methods

Ten girls with adolescent idiopathic scoliosis affecting the thoracic spine were studied before and 17–23 months (mean=19·6, SD=1·9) after spinal fusion with insertion of a Harrington rod. Their ages ranged from 13 to 15 years (mean=13·8, SD=0·9) when first tested. None had any cardiac or respiratory disease complicating the scoliosis. The angle of scoliosis was measured before and after operation by the method of Cobb (1948). The weight, height, and arm span were also measured (table 1).

Peak flow rate (PEFR) was measured with a Wright peak flow meter, the forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) with a dry spirometer (Vitalograph), and maximum voluntary ventilation (MVV) with a low resistance nine-litre wet spirometer (P K Morgan).

Exercise was performed on a bicycle ergometer against progressively increasing loads, and minute ventilation, tidal volume, respiratory frequency, oxygen uptake, and heart rate were recorded. The details of the methods are described in an earlier paper (Shneerson, 1978b).

The regression coefficients of the minute ventilation ($\dot{V}E$) and heart rate (HR) on oxygen uptake ($\dot{V}O_2$) were calculated over the linear part of the relationships by the least squares method. The $\dot{V}E$ and HR responses were expressed as maximal values ($\dot{V}E$ max; HR max) and at interpolated values of $\dot{V}O_2$ of 0·75 l, 1·0 l, and 1·5 l ($\dot{V}E$ 0·75, $\dot{V}E$ 1·0, $\dot{V}E$ 1·5; HR 0·75, HR 1·0, HR 1·5) (Cotes, 1969; Spiro *et al*, 1974).

The observed results have been corrected to allow for the growth of the subjects between the two tests (table 1). The PEFR, FEV_1, and FVC have been expressed as percentage predicted values according to arm span (Godfrey *et al*, 1970), $\dot{V}O_2$ max has been corrected for body weight

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Table 1 *Personal data of ten patients*

		Angle of scoliosis (degrees)	Weight (kg)	Height (cm)	Arm span (cm)
Before spinal fusion	Range	50–84	38–61	147–170	155–177
	Mean	65·8	49·1	158·7	168·4
	SD	11·3	6·4	6·7	6·1
After spinal fusion	Range	13–36	44–67·5	155–173	163–178
	Mean	27·3	55·2	164·2	172·7
	SD	8·0	7·6	5·5	4·6

(Davies *et al*, 1972), V_T max for vital capacity, and the submaximal heart rate indices for body weight (Jones *et al*, 1975).

Results

PEAK FLOW RATE, SPIROMETRY, AND MAXIMUM VOLUNTARY VENTILATION

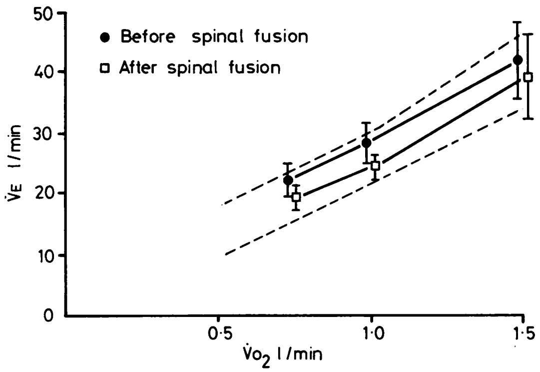
The results before and after spinal fusion are shown in table 2. The absolute values for PEFR, FEV_1, and FVC increased by 9·1–15·9% after surgery. When the values, however, were corrected for the increase in arm span between the two tests (Godfrey *et al*, 1970), the differences were not statistically significant. The MVV also increased slightly but not significantly after spinal fusion.

MAXIMUM OXYGEN UPTAKE

The small increase in $\dot{V}O_2$ max after surgery (table 3) disappeared when it was corrected for body weight (Davies *et al*, 1972).

MINUTE VENTILATION

$\dot{V}_E$ max hardly altered during the interval between the two tests (table 3) and there was little change in the mean dyspnoeic index ($\dot{V}_E$ max/MVV× 100%) (before fusion: mean=65·4%, SD=14·4; after fusion: mean=63·2%, SD=19·7). The submaximal minute ventilation was significantly improved at $\dot{V}O_2$ of 0·75 l ($P<0·05$) and 1·0 l ($P<0·01$) by surgery (figure).



Effect of spinal fusion on minute ventilation ($\dot{V}_E$). Normal values ±1 SD (Jones et al, 1975) are shown by broken lines and observed values are shown ±1 SD. Postspinal fusion values significantly improved at V_{O_2} of 0·75 l ($P<·05$) and 1·0 l ($P<·01$).

Table 2 *Results of resting lung function tests*

		PEFR (l/min) Observed	PEFR % predicted	FEV_1 (l) Observed	FEV_1 % predicted	FVC (l) Observed	FVC % predicted	MVV (l/min) Observed
Before spinal fusion	Mean	416	90·1	2·51	77·8	2·76	72·5	91·7
	SD	38	5·3	0·26	6·0	0·36	7·8	19·1
After spinal fusion	Mean	454	94·8	2·91	85·7	3·18	78·9	99·8
	SD	30	7·5	0·34	9·3	0·47	10·3	20·5

Table 3 *Indices of maximal exercise*

		$\dot{V}O_2$ max l/min	$\dot{V}O_2$ max ml/kg/min	$\dot{V}_E$ max l/min	V_T max (l)	V_T max × 100% / VC	HR max beats/min
Before spinal fusion	Mean	1·70	34·6	58·94	1·73	57·0	182·7
	SD	0·39	7·1	10·10	0·40	11·2	14·3
After spinal fusion	Mean	1·83	33·6	62·40	1·86	58·4	185·0
	SD	0·30	5·3	12·26	0·77	8·4	7·5

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PATTERN OF VENTILATION

There was a small but insignificant increase in V_T max after spinal fusion, and this remained insignificant when it was corrected for the increase in vital capacity between the two tests (table 3).

HEART RATE

The mean maximal heart rate was similar in the two tests (table 3). The submaximal heart rate indices at V_{O_2} of 0·75 l and 1·0 l were all lower after surgery ($P<0.05$) (table 4), but when they were corrected for weight gain between the tests (Jones *et al,* 1975) the improvement disappeared.

complicated by the growth that had taken place between the two tests. Several indices of exercise performance, such as the heart rate (Cotes *et al,* 1973), vary with body dimensions, and these have had to be taken into account in comparing the results. Thus the maximal oxygen uptake has been expressed as ml/kg body weight/min, maximal tidal volume as a percentage of the vital capacity, and the submaximal heart rates as percentages of the predicted value according to body weight. The usual prediction of PEFR, FEV_1, and FVC from height is valueless because straightening of the spine increases the height independently of any growth. Values predicted from the arm span (Godfrey *et al,* 1970) were therefore used.

Table 4 *Heart rate during submaximal exercise*

		HR 0·75 (n=10)		*HR 1·0 (n=10)*		*HR 1·5 (n=7)*	
		Observed	*% predicted*	*Observed*	*% predicted*	*Observed*	*% predicted*
Before spinal fusion	Mean	132·2	111·5	147·3	106·7	168·9	102·4
	SD	12·8	13·9	15·5	14·8	19·3	16·2
After spinal fusion	Mean	116·2	104·0	131·7	102·5	161·3	107·6
	SD	10·4	11·4	9·7	11·1	11·7	9·7

Discussion

Several previous authors have studied the cardiorespiratory effects of spinal fusion performed for scoliosis. The vital capacity and MVV have been found to be unaffected by spinal fusion (Makley *et al,* 1968; Westgate and Moe, 1969; Lamarre *et al,* 1971; Shannon *et al,* 1971; Meister and Heine, 1973; Stoboy and Speierer, 1975; Henche *et al,* 1977) or to increase slightly after it (Gazioglu *et al,* 1968; Lindh and Bjure, 1975). Small increases in Pa_{O_2} (Shannon *et al,* 1971; Meister and Heine, 1973) and Sa_{O_2} (Westgate and Moe, 1969) have been found, and Shannon *et al* (1971) observed an improvement in the physiological dead space and $PA\text{-}a_{O_2}$ as well. A marginal increase in V_{O_2} max during exercise (Stoboy and Speierer, 1975) and an improvement in Pa_{O_2} after exercise (Shannon *et al,* 1971) are the only changes in response to exercise after spinal fusion that have been reported.

None of the 10 subjects of this study had any cardiorespiratory disease complicating the scoliosis. They underwent identical resting and exercise tests under the same conditions before and after surgery. Postoperatively they had spent four months in a plaster of Paris jacket and then worn a Milwaukee brace until a year after surgery. All had returned to full activity at least five months before being retested, and none had any cardiac or respiratory symptoms when they were retested.

Estimation of the effect of spinal fusion was

Spinal fusion considerably decreased the angle of scoliosis in all the subjects, but the changes in PEFR, FEV_1, FVC, and MVV were much less striking. The slight improvements after spinal fusion were not statistically significant. The small increase in V_{O_2} max was due to the growth of the subjects as it disappeared when the correction for body weight was applied. There was, however, a statistically significant improvement in submaximal ventilation at V_{O_2} of 0·75 and 1·0 l/min, although it was of a small amount. There was no increase in V_E max and the maximal V_T both in absolute volumes and expressed as a percentage of vital capacity remained unchanged. The apparent slowing of the submaximal heart rate indices after spinal fusion was abolished by correcting for the increase in body weight between the tests and did not represent a true physiological improvement.

Thus the anatomical improvement of the scoliosis after spinal fusion is far greater than the physiological changes during exercise shown in this study. The only significant improvement, after allowing for growth between the tests, was a small decrease in the submaximal ventilatory indices. Possibly, however, spinal fusion prevented a deterioration in exercise performance that would otherwise have occurred in the interval between the tests. The long-term effects of spinal fusion on the development of respiratory failure and pulmonary hypertension are unknown, but the im-

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provement in PaO_2 that has been shown (for instance Shannon *et al,* 1971) may delay or prevent these complications.

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References

Bergofsky, E H, Turino, G M, and Fishman, A P (1959). Cardiorespiratory failure in kyphoscoliosis. *Medicine*, **38**, 263–317.

Cobb, J R (1948). Outline for the study of scoliosis. In *American Academy of Orthopaedic Surgeons; Instructional Course Lectures*, **5**, 261–275.

Cotes, J E (1969). Relationships of oxygen consumption, ventilation, and cardiac frequency to body weight during standardised submaximal exercise in normal subjects. *Ergonomics*, **12**, 415–427.

Cotes, J E, Berry, G, Burkinshaw, L, Davies, C T M, Hall, A M, Jones, P R M, and Knibbs, A V (1973). Cardiac frequency during submaximal exercise in young adults: relation to lean body mass, total body potassium and amount of leg muscle. *Quarterly Journal of Experimental Physiology*, **58**, 239–250.

Davies, C T M, Barnes, C, and Godfrey, S (1972). Body composition and maximal exercise performance in children. *Human Biology*, **44**, 195–214.

Gazioglu, K, Goldstein, L A, Femi-Pearse, D, and Yu, P N (1968). Pulmonary function in idiopathic scoliosis. *Journal of Bone and Joint Surgery*, **50A**, 1391–1399.

Godfrey, S, Kamburoff, P L, and Nairn, J R (1970). Spirometry, lung volumes and airway resistance in normal children aged 5–18 years. *British Journal of Diseases of the Chest*, **64**, 15–24.

Henche, H R, Morscher, E, Rutishauser, M (1977). Die Entwicklung der Lungenfunktion nach Skoliosebehandlung durch Harrington-Instrumentation. *Zeitschrift für Orthopädie*, **115**, 816–820.

Jones, N L, Campbell, E J M, Edwards, R H T, and Robertson, D G (1975). *Clinical Exercise Testing*. W B Saunders, Philadelphia.

Lamarre, A, Hall, J E, Weng, T R, Aspin, N, Levison, H (1971). Pulmonary function in scoliosis one year after surgical correction. *Journal of Bone and Joint Surgery*, **53A**, 195.

Larmi, T K I, Pätiälä, J, and Karvonen, M J (1955). Studies of pulmonary function in kyphoscoliosis after tuberculous spondylitis. *Annales Medicinae Internae Fenniae*, **44**, 57–69.

Lindh, M, and Bjure, J (1975). Lung volumes in scoliosis before and after correction by the Harrington instrumentation method. *Acta Orthopaedica Scandinavica*, **46**, 934–948.

Makley, J T, Herndon, C H, Inkley, S, Doershuk, C, Matthews, L W, Post, R H, and Littell, A S (1968). Pulmonary function in paralytic and non-paralytic scoliosis before and after treatment. *Journal of Bone and Joint Surgery*, **50A**, 1379–1390.

Meister, R, and Heine, J (1973). Vergleichende Untersuchungen der Lungenfunktion bei jugendlichen Skoliosepatienten vor und nach der Operation nach Harrington. *Zeitschrift für Orthopädie*, **111**, 749–755.

Shannon, D C, Riseborough, E J, Kazemi, H (1971). Ventilation perfusion relationships following correction of kyphoscoliosis. *Journal of American Medical Association*, **217**, 579–584.

Shneerson, J M (1978a). Pulmonary artery pressure in thoracic scoliosis during and after exercise while breathing air and pure oxygen. *Thorax*, **33**, 747–754.

Shneerson, J M (1978b). The cardiorespiratory response to exercise in thoracic scoliosis. *Thorax*, **33**, 457–463.

Shneerson, J M, Sutton, G C, and Zorab, P A (1978). Causes of death, right ventricular hypertrophy and congenital heart disease in scoliosis. *Clinical Orthopaedics and Related Research*, **135**, 52–57.

Spiro, S G, Juniper, E, Bowman, P, and Edwards, R H T (1974). An increasing work rate test for assessing the physiological strain of submaximal exercise. *Clinical Science and Molecular Medicine*, **46**, 191–206.

Stoboy, H, and Speierer, B (1975). Lungenfunktion und spiroergometrische Parameter während der Rehabilitation von Patienten mit idiopathischer Skoliose (Fusionoperation der WS nach Harrington und Training). *Archiv für orthopädische und Unfall-Chirurgie*, **81**, 247–254.

Westgate, H D, and Moe, J H (1969). Pulmonary function in kyphoscoliosis before and after correction by the Harrington instrumentation method. *Journal of Bone and Joint Surgery*, **51A**, 935–946.

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