

## Ambulatory oxygen therapy in stable kyphoscoliosis

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*Ambulatory oxygen therapy in stable kyphoscoliosis. D.J. Meecham Jones, E.A. Paul, J.H. Bell, J.A. Wedzicha. ©ERS Journals Ltd 1995.*

**ABSTRACT:** Patients with chronic obstructive pulmonary disease (COPD) may benefit from ambulatory oxygen; however, the effect of exercise on arterial oxygen saturation ( $S_{a,O_2}$ ) in patients with kyphoscoliosis and of correction with ambulatory oxygen have not been previously reported.

Twelve patients with stable kyphoscoliosis (mean (SD) Cobb angle  $79 (26)^\circ$ ) were studied, with mean (SD) arterial oxygen tension ( $P_{a,O_2}$ ) 8.96 (0.93) kPa, arterial carbon dioxide tension ( $P_{a,CO_2}$ ) 6.52 (0.66), forced expiratory volume in one second (FEV<sub>1</sub>) 0.90 (0.15) L, forced vital capacity (FVC) 1.34 (0.46) L. Six-minute walking tests with oximetry and visual analogue scores (VAS) for breathlessness were performed on air (baseline), and with cylinders containing air and oxygen at 2 L·min<sup>-1</sup>. Cylinder walks were in random order, with patients blinded to cylinder content.

Patients showed oxygen desaturation at each stage of the study. At baseline, oxygen desaturation during exercise was correlated with deterioration in VAS breathlessness scores. Ambulatory oxygen produced significant improvements in desaturation, breathlessness scores and recovery time compared to baseline and air cylinder walks. There was no relationship between baseline desaturation and changes in walking distance. Although exercise desaturation, breathlessness and recovery times were significantly improved with ambulatory oxygen at 2 L·min<sup>-1</sup>, walking distance was unaffected.

We conclude that patients with moderate to severe kyphoscoliosis have significant oxygen desaturation on exercise and should thus routinely receive oximetry on exercise and assessment for ambulatory oxygen therapy.

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The addition of oxygen during exercise has been shown to be beneficial in patients with chronic obstructive pulmonary disease (COPD) and interstitial lung disease, with improvements in exercise tolerance and alleviation of breathlessness [1–6]. This improvement in exercise capacity with ambulatory oxygen has been shown to be related to the degree of arterial oxygen desaturation during walking tests on room air [5]. Patients with chronic heart failure also experience a fall in arterial oxygen saturation ( $S_{a,O_2}$ ) on exercise, though supplemental oxygen has no effect on exercise capacity or breathlessness [7].

Patients with chest wall disorders, such as kyphoscoliosis, have impaired exercise capacity and may be disabled by breathlessness. However, there is no information available as to whether these patients show any fall in oxygen saturation on exercise, or whether these patients may derive any benefit from the addition of supplemental oxygen.

The aim of this study was to investigate the physiological effects of exercise in a group of patients with stable respiratory impairment due to moderate to severe kyphoscoliosis. We also investigated the effects of supplemental oxygen during exercise in this patient group.

### Patients and Methods

#### Patients

The study was approved by the Ethics Committee of the Royal Brompton, National Heart and Lung Hospitals, and informed written consent was obtained from all patients. Twelve patients (6 males and 6 females, median (range) age 61 (43–78) yrs) were studied. All had long-standing respiratory impairment due to kyphoscoliosis, and had been in a stable clinical state with no exacerbations for at least 4 weeks prior to the study. Six patients were established on domiciliary nasal intermittent positive pressure ventilation, and one patient was additionally using domiciliary oxygen therapy. At the start of the study, mean (SD) forced expiratory volume in one second (FEV<sub>1</sub>), was 0.90 (0.15) L (36 (9) % predicted), forced vital capacity (FVC) 1.34 (0.46) L (46 (16) % pred), arterial oxygen tension ( $P_{a,O_2}$ ) (on room air) 8.96 (0.93) kPa, arterial carbon dioxide tension ( $P_{a,CO_2}$ ) 6.52 (0.66) kPa. Individual data are displayed in table 1, along with Cobb angles, a measure of the severity of the spinal curvature. These are derived by drawing lines parallel to the superior border of the highest vertebra

Table 1. – Patient characteristics

Pt. No.	Age yrs	Sex	Cobb angle°	FEV <sub>1</sub> L	FVC L	Pa <sub>a</sub> O <sub>2</sub> kPa	Pa <sub>a</sub> CO <sub>2</sub> kPa
1	48	F	28	1.20	2.60	8.96	5.57
2	78	F	96	0.80	1.00	10.10	5.28
3	59	F	74	0.67	0.89	6.86	7.60
4	59	M	75	0.90	1.20	8.16	6.88
5	57	M	73	0.89	1.20	9.27	7.26
6	63	F	110	0.84	1.20	8.56	7.01
7	66	M	66	1.10	2.00	8.91	6.62
8	52	F	79	1.00	1.35	9.67	6.41
9	70	M	96	0.74	1.00	9.18	6.91
10	43	M	38	1.10	1.40	10.30	5.74
11	71	M	97	0.78	1.20	7.97	6.42
12	70	M	120	0.89	1.10	9.56	6.61
Mean (sd)			79 (26)	0.90 (0.15)	1.34 (0.46)	8.96 (0.93)	6.52 (0.66)

Pt: patients; M: male; F: female; FEV<sub>1</sub>: forced expiratory volume in one second; FVC: forced vital capacity; Pa<sub>a</sub>O<sub>2</sub>: arte-

involved in the curvature and the inferior border of the lowest vertebra as seen on an anteroposterior roentgenogram of the spine, drawing perpendiculars to these lines, and measuring the angle of intersection of the perpendiculars [8]. The mean Cobb angle was 79 (26)°, indicative of moderate to severe kyphoscoliosis.

### Methods

Spirometry (FEV<sub>1</sub>, FVC) was assessed prior to the start of the study using a rolling seal spirometer (P.K. Morgan, Rainham, UK). Resting blood gases (on room air) were obtained from the radial artery, and analysed immediately on a blood gas analyser (Ciba-Corning 278 Blood Gas Analyser, Medfield, Ma, USA).

Standard 6-min walking tests [9] were performed, according to the following protocol: 1) practice walk; 2) baseline walk without cylinder to assess normal exercise capacity and the degree of oxygen desaturation. Each patient subsequently performed two further walks in random order: one walk 3) carrying an air cylinder (DeVilbiss Health Care (UK) Ltd, Middlesex, UK); and the other 4) carrying an identical cylinder containing oxygen. In each case, gas flow was set at 2 L·min<sup>-1</sup> via nasal cannulae and the patient was blinded to cylinder content. There was a rest period of at least 1 h between walks, and patients received no bronchodilators for at least 2 h before walks. All walks were performed in the same length of measured hospital corridor and were supervised by the same investigator. Subjects were instructed to walk as far as possible in 6 min, stopping if necessary. However no active encouragement was given.

Continuous oxygen saturation (Sa<sub>a</sub>O<sub>2</sub>) was monitored during all walking tests via finger electrode (Minolta Pulsox 7, AVL Instruments, Switzerland), and minimum desaturation was recorded for each test. Walking distance and recovery time to starting Sa<sub>a</sub>O<sub>2</sub> on completion of the walk were also recorded for each test, along with

the number of stops and their duration. Breathlessness was assessed at the start and finish of each test using standard 10 cm visual analogue scale scores (VAS) [10], rating breathlessness from "not at all breathless" (zero) to "extremely breathless" (10 cm). All assessments for individual patients were completed on the same day.

### Statistical Methods

Oxygen desaturation, walking distance and breathlessness VAS scores were not normally distributed, thus statistical analysis was based on non-parametric techniques. Wilcoxon's matched pairs signed rank test was used to compare median changes. Spearman's correlation coefficient was used to describe the association between continuous variables. The computer programs used in the analysis were SPSS/PC (Release 5.0, 1992, SPSS Inc., Chicago, IL, USA) and Minitab (Release 7.1, 1989, Minitab Inc.).

### Results

On exercise, all patients showed significant falls in oxygen saturation. Two of the 12 patients needed to stop during walking tests; in each case, the minimum desaturation achieved prior to the stop was the same as on completion of the full 6-min walk. There were no significant differences in the fall in Sa<sub>a</sub>O<sub>2</sub>, distance walked or VAS scores between baseline and air cylinder walks, suggesting no carrying effect and no measurable placebo effect associated with the portable cylinders used. On baseline walks, median (range) saturation fell from 94% (86–97%) at rest to 81.5% (59–91%) on exercise, median change -12.5% (3–27%) (p=0.0001). For air cylinder walks, median (range) Sa<sub>a</sub>O<sub>2</sub> fell from 93.5% (86–96%) at rest to 80.5% (66–87%), median change -13% (8–21%) (p=0.0001). With ambulatory oxygen, the median fall in Sa<sub>a</sub>O<sub>2</sub> was at 4% (1–16%), significantly lower than for baseline (p=0.008) or air cylinder (p=0.003) walks. Individual and median changes in Sa<sub>a</sub>O<sub>2</sub> are shown in figure 1.

Figure 2 depicts the median VAS scores for breathlessness at end-exercise at each stage of the study. There was a significant improvement in breathlessness scores on oxygen compared with baseline (p=0.02) and air cylinder walks (p=0.002). For baseline walks, the degree of oxygen desaturation was correlated with the change in VAS score between start and finish of the walks (r<sub>s</sub>=0.61); the greater the degree of desaturation, the worse the score for breathlessness, as shown in figure 3. This relationship did not apply when desaturation was improved or corrected with ambulatory oxygen.

There was no difference in the median walking distance between the baseline (337.5 (270–430) m), air cylinder (350 (265–430) m) or oxygen cylinder walks (375 (290–430) m) (fig. 4). The changes in walking distance and breathlessness scores with portable oxygen were not correlated with the degree of arterial oxygen desaturation on baseline walks. Median recovery time improved from 95 (30–250) s with air to 25 (0–110) s with oxygen (p=0.002).

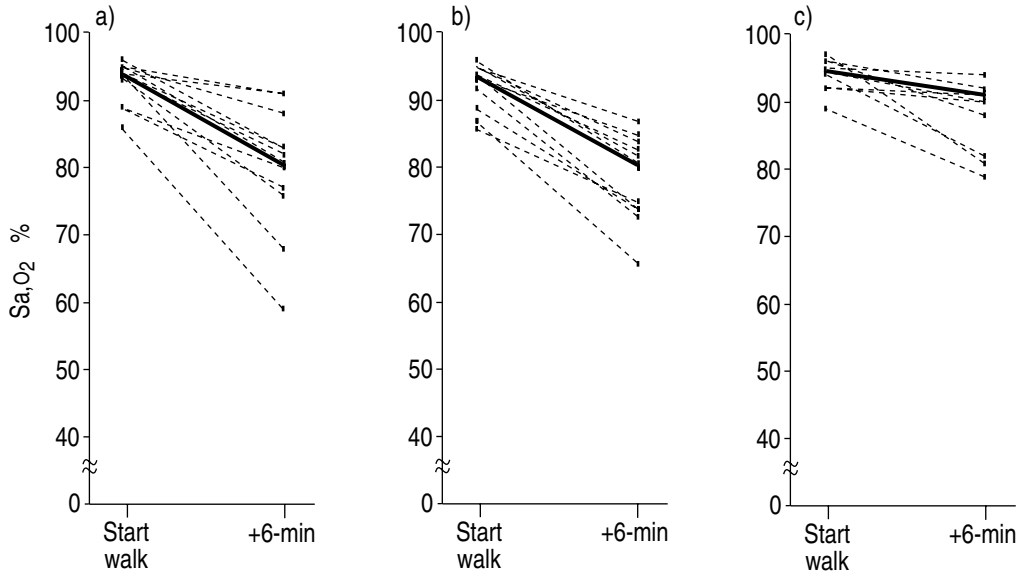


Fig. 1. – Individual (dotted lines) and median changes (solid line) in arterial oxygen saturation ( $S_{a,O_2}$ ) for: a) baseline; b) air cylinder; and c) supplemental oxygen cylinder ( $2\text{ L}\cdot\text{min}^{-1}$ ) walks ( $n=12$ ).

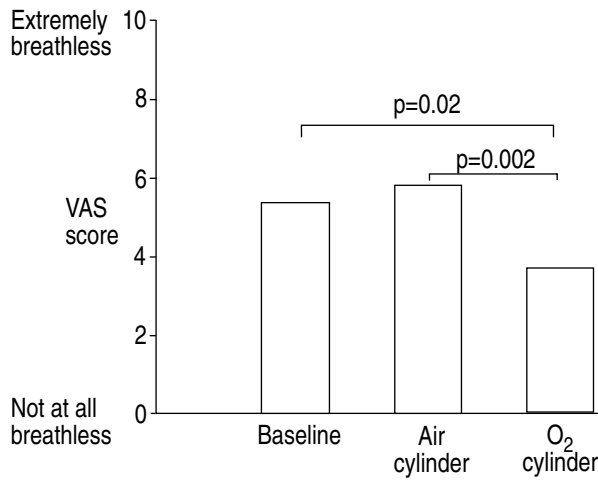


Fig. 2. – Median visual analogue scale (VAS) scores for breathlessness for baseline, air cylinder and oxygen cylinder walks. Higher scores indicate increasing severity of symptoms.

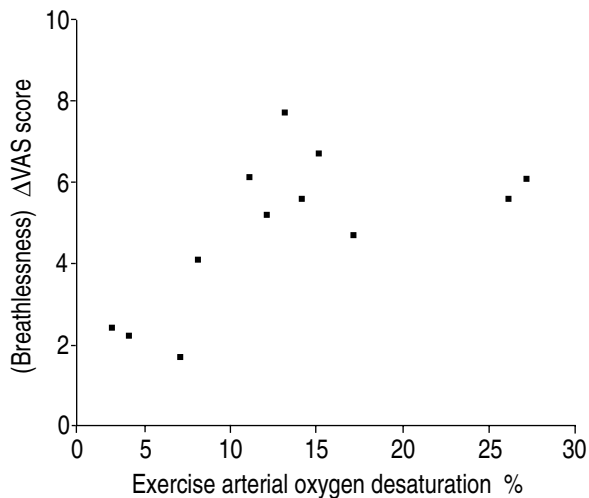


Fig. 3. – Correlation between degree of oxygen desaturation and change in breathlessness (visual analogue scale (VAS) score) between start and finish of test on baseline exercise walking tests ( $r_s=0.61$ ;  $p<0.05$ ).

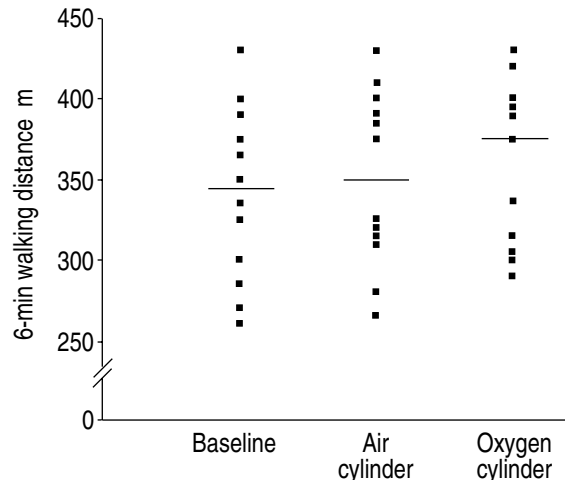


Fig. 4. – Individual and median 6-min walking distances for baseline, air cylinder and oxygen cylinder walks ( $n=12$ ).

There was no correlation between the 6-min walking distance and VAS scores for breathlessness at baseline and the degree of spinal deformity, determined by the angle of Cobb.

### Discussion

Exertional dyspnoea is a common and disabling symptom in many patients with kyphoscoliosis. Although ambulatory oxygen therapy has been shown to be beneficial in COPD, there are no studies describing the effect of supplemental oxygen on exercise capacity and symptoms of breathlessness in patients with restrictive chest wall disease. As in patients with COPD, we have shown that patients with moderate to severe kyphoscoliosis show significant falls in oxygen saturation during exercise, which can be corrected with the addition of ambulatory oxygen. In addition, symptoms of breathlessness and recovery times to baseline saturation were significantly

improved with oxygen therapy. In contrast to patients with COPD, there was no improvement in 6-min walking distance. However, in view of the fact that only two of the 12 subjects needed to stop during walks, it may be that endurance walking tests would prove a more sensitive measure.

Patients with kyphoscoliosis are subject to a variety of mechanical factors which eventually contribute to alveolar hypoventilation [11, 12]. With progressive disease, total lung capacity (TLC), vital capacity (VC) and functional residual capacity (FRC) are markedly reduced, mainly due to reductions in chest wall compliance and alterations in the mid-position of the thoracic cage. In particular, inspiratory capacity and expiratory reserve volume may be reduced out of proportion to residual volume. There may also be abnormalities of transfer factor [13] and ventilation-perfusion relationships throughout the lungs, although in most cases this is of less significance than the mechanical problems.

At rest, minute ventilation is reduced due to diminished tidal volume. However, on exercise, the mechanical effects of chest wall deformity assume greater significance and hypoventilation is more marked. Due to the reduced compliance of chest wall and lungs seen in kyphoscoliosis, any attempt to increase tidal volume is associated with a marked increase in the oxygen cost of breathing [12], particularly in older patients in whom there is greater rigidity of the chest wall. The mechanical impairment, coupled with the low inspiratory capacity, results in very marked respiratory limitation when respiratory demands increase on exercise, and hence oxygen desaturation. A previous study of incremental exercise in patients with a similar degree of deformity showed that maximal oxygen consumption ( $\dot{V}'\text{o}_2\text{max}$ ) was significantly reduced compared with age-matched controls, with reduced minute ventilation. In the majority of these patients, exercise was limited by ventilatory factors, whereas in normal subjects exercise is limited by circulatory factors.

It is likely that the failure to improve exercise capacity in this study was due to mechanical factors, which may explain why these patients differ from those with COPD. However, other factors may be involved. A study of young adults with lesser degrees of kyphoscoliosis showed that exercise capacity was impaired even when there was no evidence of significant ventilatory impairment [14]. The authors concluded that this was likely to be due to a general physical deconditioning, in this instance possibly due to awareness of the deformity and subsequent reluctance to undertake physical activity. In addition, patients with more advanced scoliosis and consequent ventilatory limitation may also undertake less frequent and less intensive exercise due to symptoms of breathlessness. It is possible that consequent respiratory and peripheral muscle wasting may play a role in further impairment of exercise capacity.

Although previous studies in COPD have shown no relationship between oxygen desaturation and breathlessness [15, 16], in this study we have shown that exertional dyspnoea in patients with kyphoscoliosis is related to the degree of arterial oxygen desaturation on a baseline walk

and can be alleviated by supplemental oxygen, although, in contrast with COPD, correction of desaturation did not improve walking distance. The mechanism underlying the improvements in breathlessness scores is probably multifactorial. It has been shown that the sensation of breathlessness is associated with the level of ventilation [17]; in patients with kyphoscoliosis, in whom ventilatory mechanics are grossly abnormal, it seems likely that this is an important mechanism in the generation of breathlessness. Supplemental oxygen during exercise has been shown to reduce minute ventilation in patients with COPD, with a consequent reduction in dyspnoea. However, in a study employing individually standardized and reproducible exercise tests it has also been shown that correction of oxygen desaturation may reduce dyspnoea independent of the level of ventilation, although the exact mechanism remains unclear [18].

We believe that ambulatory oxygen therapy may be an important addition to current standard therapy in patients with moderate to severe kyphoscoliosis, although studies of portable oxygen in COPD have shown no evidence of alteration in survival, despite improvements in exercise tolerance. In this study, we did not demonstrate an immediate effect on exercise capacity. However, there were significant improvements in oxygen desaturation and dyspnoea scores, and studies of the longer term effects of ambulatory oxygen therapy in kyphoscoliosis are now indicated. It is possible that, by improving dyspnoea, ambulatory oxygen therapy may facilitate an improvement in levels of activity and a consequent restoration of physical conditioning with improved exercise tolerance, particularly if used as part of a structured exercise or rehabilitation programme. We suggest that exercise studies should be performed routinely in all patients with moderate to severe kyphoscoliosis, to assess suitability for long-term ambulatory oxygen therapy.

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