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Effects of breathing supplemental oxygen before progressive exercise in patients with chronic obstructive lung disease

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ABSTRACT A study was carried out to determine whether supplemental oxygen before exercise would improve maximum exercise performance and relieve exertional dyspnoea in 20 patients with chronic obstructive lung disease (mean FEV_1 0·79 l; forced vital capacity 2·30 l). Patients performed two progressive treadmill exercise tests to a symptom limited maximum, with at least 30 minutes rest between tests. They received compressed air or supplemental oxygen from nasal prongs for 10 minutes before exercise in a double blind randomised trial with a crossover design. Heart rate and breathlessness score on a visual analogue scale were compared between tests at 75% of the maximum distance walked in the compressed air test. The mean arterial oxygen saturation (Sao_2) after oxygen (93%) was significantly higher than after compressed air (91%). There was no significant change, however, in maximum distance walked or maximum heart rate, or in the breathlessness score or heart rate at 75% of maximum distance walked. The study had a power of 93% for detecting an increase of 50 metres in maximum distance walked. There was an order effect, with better performance on the second test; but the magnitude of the difference was small. It is concluded that administration of supplemental oxygen sufficient to raise Sao_2 above 90% for 10 minutes before exercise is unlikely to improve maximum exercise performance or breathlessness on exertion in patients with chronic obstructive lung disease.

Supplemental oxygen improves exercise performance and relieves dyspnoea when used during exercise by patients with chronic obstructive lung disease.[1-4] Portable oxygen, however, is inconvenient and expensive and the extra weight carried by the patient sometimes outweighs the gains from oxygen.[3] There is conflicting evidence on whether supplemental oxygen before exercise improves exercise performance and exercise related dyspnoea. In 1981 Woodcock *et al*[1] showed benefit from pre-exercise oxygen in 10 patients with chronic obstructive lung disease, and this has been cited in a recent review of treatment for chronic bronchitis and emphysema.[5] Rhind *et al*,[6] however, recently failed to show improvement in distance walked or in breathlessness in 12 patients with chronic bronchitis when "predosed" with supplemental oxygen before exercise. We have therefore conducted a double blind trial of oxygen and compressed air given before a progressive maximal exercise test in 20 patients with chronic obstructive lung disease, to determine whether "predose" supplemental oxygen improves maximal exercise performance and relieves breathlessness during exercise by comparison with placebo.

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Methods

We studied 20 consecutive patients with chronic obstructive lung disease referred for assessment of their need for home oxygen therapy. All patients gave informed consent. Patients had chronic airflow obstruction (FEV_1/forced vital capacity (FVC) < 60%, total lung capacity (TLC) > 80% predicted), with no significant change after bronchodilator. Patients were not studied during exercise if there was a history of angina, recent myocardial infarction, exercise induced syncope, or left ventricular failure. All patients under-

went routine pulmonary function testing, including measurement of lung volumes by body plethysmography and carbon monoxide gas transfer (TLCO) by a single breath method. Spirometry was measured before and 15 minutes after 5 mg nebulised salbutamol. Arterial blood was drawn from the radial artery, while the patient was seated after resting for 15 minutes, and analysed for pH, oxygen tension (P_{O_2}) and carbon dioxide tension (P_{CO_2}) with standard electrodes (Radiometer ABL-2). In addition, arterial oxygen saturation (Sa_{O_2}) was measured with an ear oximeter (Biox 3700, Ohmeda, Colorado). If the resting Sa_{O_2} was under 90%, the oxygen flow rate required to achieve an Sa_{O_2} of at least 90% was recorded. The haemoglobin concentration, chest radiograph, and electrocardiograph were assessed before study.

Patients were randomised to receive compressed air or supplemental oxygen by nasal prongs at 2·5 l min^{-1} for 10 minutes before the first exercise test. This flow rate of oxygen was enough to raise resting Sa_{O_2} to at least 90% in all patients when seated. Neither the patient nor the operator knew whether compressed air or supplemental oxygen had been given. Patients were told that both cylinders contained oxygen, but in different concentrations. All patients had done at least one practice walk on the treadmill before the study. Each patient performed two progressive exercise tests on the treadmill (Repco Equipment Company, Sydney) until limited by symptoms, with at least 30 minutes' rest between each test. The gradient was kept flat throughout the test. The starting speed was 1·5 km/h with increments of 0·5 km/h every minute. All patients exercised to their maximum and all were limited by dyspnoea. During exercise the heart rate and oxygen saturation were monitored by ear oximetry (Biox IIA, Ohmeda, Colorado). Breathlessness was assessed by a 300 mm visual analogue scale,[7] scores being recorded before and each minute during exercise. The maximum distance walked was recorded for each test. Heart rate and visual analogue scale scores were compared at a distance equal to 75% of the maximum distance walked with compressed air (VAS75, HR75).

Comparisons between tests were made by paired *t* tests. The power of the study was calculated by a standard formula.[8]

Results

Of the 20 patients, 13 were men and seven women. Fourteen had physiological evidence of emphysema, two had bronchiectasis, and four had chronic bronchitis. Table 1 shows anthropometric data and pulmonary function for the group.

Table 2 shows results of the exercise tests. The mean (SEM) Sa_{O_2} at rest before exercise was higher after oxygen (93% (1%)) than after compressed air (91% (1%)) ($p < 0·01$, 95% confidence limits of the difference 1–3%). The end exercise Sa_{O_2}, however, was not significantly different, nor was there any significant difference in maximum distance walked, VAS75, or HR75 between compressed air and oxygen. There were no significant differences in mean visual analogue scale scores at any time during exercise between the compressed air and oxygen tests (fig 1). There was also no significant difference in mean heart rate between the compressed air and oxygen tests at any time.

When the group was stratified according to resting Sa_{O_2} and Pa_{CO_2}, 11 patients had a resting Sa_{O_2} above 90% and eight patients had a resting Pa_{CO_2} of 43 mm Hg (5·7 kPa) or more. Neither resting Sa_{O_2} nor Pa_{CO_2} altered the finding of no significant difference between the compressed air and oxygen tests in maximum distance walked, VAS75, and HR75.

Table 1 *Anthropometric data and pulmonary function in 20 patients with chronic obstructive lung disease*

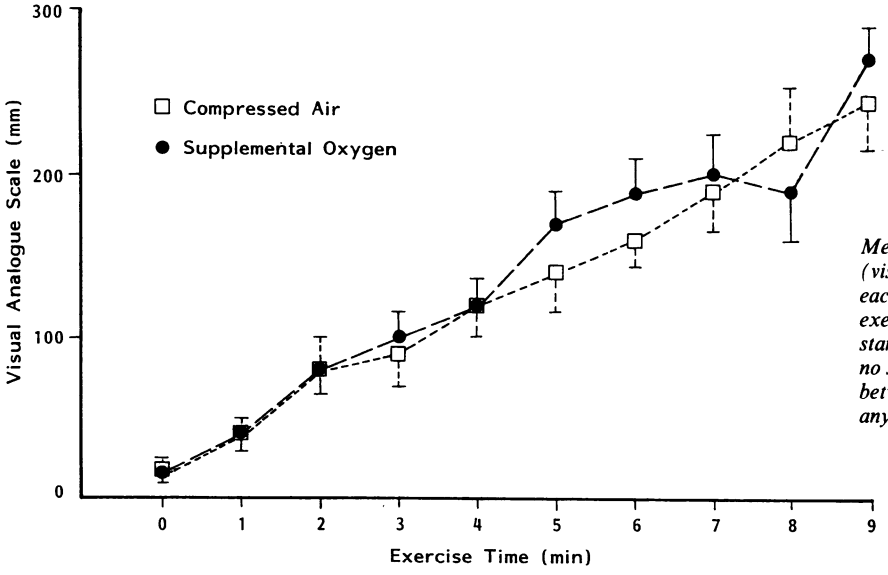
	Mean	*SD*	*Range*
Age (years)	63·2	10	42–74
Height (cm)	165	9	150–182
Weight (kg)	62	14	38–94
FEV_1 (l)	0·79	0·29	0·45–1·50
FEV_1 (% pred)	31	13	17–62
FVC (l)	2·30	0·70	1·00–3·85
FVC (% pred)	68	17	35–121
RV (% pred)	206	60	100–334
TLC (% pred)	122	24	80–183
TLCO (% pred)	55	32	6–120
pH	7·43	0·04	7·35–7·56
Pa_{O_2} (mm Hg)	58	9	43–82
Pa_{CO_2} (mm Hg)	44	9	31–62
HCO_3 (mmol/l)	28·8	5·6	21·8–39·6
Oximeter Sa_{O_2} (%)	90	3	84–96

Conversion: Traditional to SI units—Blood gas tensions: 1 mm Hg = 0·133 kPa.
FVC—forced vital capacity; RV—residual volume; TLC—total lung capacity; TLCO—carbon monoxide transfer factor; Pa_{O_2}—arterial oxygen tension; Pa_{CO_2}—arterial carbon dioxide tension; HCO_3—plasma bicarbonate; Sa_{O_2}—arterial oxygen saturation.

Table 2 *Results (means with standard errors in parentheses) of exercise tests performed after compressed air (CA) and supplemental oxygen (O_2)*

	CA test	*O_2 test*
Resting Sa_{O_2} (%)	91 (1)	93 (1)*
End exercise Sa_{O_2} (%)	83 (2)	84 (2)
DISTmax (m)	272 (40)	274 (35)
VAS75 (mm)	182 (9)	182 (16)
HR75 (beats/min)	123 (4)	122 (4)
HRmax (beats/min)	127 (5)	129 (4)
Exercise duration (min)	5·5 (0·6)	5·7 (0·5)

*Significantly different from CA by paired *t* test; $p < 0·01$; 95% confidence limits of difference in Sa_{O_2} = 1 − 3%.
Sa_{O_2}—arterial oxygen saturation; DISTmax—maximum distance walked; HR75—heart rate at 75% of the maximum distance walked.



Mean breathlessness score (visual analogue scale) at each minute during treadmill exercise. Bars indicate standard errors. There was no significant difference between air and oxygen at any stage.

When the order effect of the tests was examined (table 3), there was no significant difference between the first and the second tests for Sao_2 at rest or end exercise, but patients walked further in the second test (288 compared with 259 m), and HR75 and VAS75 were lower in the second test; the differences were not, however, significant at the 0·05 level.

Discussion

In 20 patients with chronic obstructive lung disease we were unable to detect a significant improvement in maximal exercise performance or breathlessness during exercise after supplemental oxygen before exercise. This is a contrast to Woodcock *et al*,[1] who studied the effect of supplemental oxygen from nasal prongs at 4 l min^{-1} for five minutes before treadmill exercise in 10 patients with chronic obstructive lung disease (mean FEV_1 0·71 l, resting Pao_2 73 mm Hg (9·7 kPa) and $Paco_2$ 34 mm Hg (4·5 kPa)). They showed that pre-exercise supplemental oxygen produced a small increase in distance walked—from 203 m to 223 m—accompanied by a small improvement in dyspnoea.

Table 3 *Results (means with standard errors in parentheses) of exercise tests in order of performance*

	1st test	*2nd test*
Resting Sao_2 (%)	92 (1)	92 (1)
End exercise Sao_2 (%)	84 (2)	83 (2)
DISTmax (m)	259 (36)	288 (39)*
VAS75 (mm)	190 (13)	173 (14)
HR75 (beats/min)	124 (4)	122 (4)
HRmax (beats/min)	127 (5)	129 (4)

*Oxygen significantly different from compressed air by paired *t* test; $p < 0·05$; 95% confidence limits of difference between means 1–56 metres.
VAS75—visual analogue scale breathlessness score at 75% of maximum distance walked. For other abbreviations see table 2.

The present study differed from that of Woodcock *et al* in several ways. Firstly, although mean age and FEV_1 were similar, our group had a lower mean Pao_2 and higher $Paco_2$. This is unlikely, however, to explain the lack of effect of oxygen in our study since oxygen had no effect in the 11 patients whose characteristics were similar to the 10 patients studied by Woodcock and associates ($Sao_2 > 90\%$, $Paco_2 < 43$ mm Hg). Secondly, our exercise protocol used linear increases in speed on the treadmill, whereas a protocol of logarithmic increases in speed was used in the Woodcock study. This meant that our patients spent about one and a quarter minutes more on the treadmill. It could be argued that our exercise protocol militated against finding an effect of pretreatment with oxygen or maximum distance walked because of the longer exercise time. We found no differences between air and oxygen, however, in terms of mean breathlessness score or heart rate at any stage during the test. Thirdly, the dosing schedule for oxygen differed between the studies. We chose a flow rate of 2·5 l min^{-1} for 10 minutes for the practical reason that low flow gauges permitting a maximum flow rate of 2·5 l min^{-1} are uniformly prescribed in our region for patients using oxygen at home. This difference in dosing schedule is unlikely to have led to differences in oxygen stores at the start of exercise between the two studies. Lastly, we studied only treadmill exercise, whereas Woodcock *et al* studied both treadmill walking and six minute corridor walking. Although the six minute

walk more closely mimics the patients' exercise at home, Woodcock *et al* found that pre-exercise supplemental oxygen increased the distance walked on both tests, but that the breathlessness score improved only in the treadmill test. The differences between the findings of the two studies are therefore unlikely to be explained by methological differences.

Our findings agree with those of Rhind *et al*,[6] who found no improvement in six minute walking distance or heart rate in 12 patients with chronic bronchitis (FEV_1 0·56 l) given supplemental oxygen for 30 minutes before exercise. In this study patients were also given supplemental oxygen or compressed air during recovery, but no reduction in recovery time was found with supplemental oxygen.

One of our authors (JLMcK) has previously studied the effects of breathing supplemental oxygen during exercise in 21 patients with chronic obstructive lung disease, using the same treadmill protocol as in the present study.[4] In that study mean maximum distance walked was significantly greater with supplemental oxygen (366 m) than with compressed air (284 m). On the basis of this finding we decided to design a study capable of detecting an increase of 50 metres in maximum distance walked. With an alpha error of 5% and a sample size of 20 patients, the beta error was 7·4% for detection of such a difference between compressed air and supplemental oxygen. Thus the power of the study to detect a clinically significant improvement in maximum distance walked was greater than 90%.

We found an order effect for the studies, with better performance in the second study. Examination of the 95% confidence limits, however, for the difference between compressed air and oxygen in maximum distance walked shows that the magnitude of this difference was small (table 3). Eleven patients had supplemental oxygen before the second study, which might have biased the study towards showing "improvement" after oxygen. Despite this, no such improvement was found.

We conclude that pretreatment with supplemental oxygen for 10 minutes before progressive maximal exercise does not improve maximum exercise performance or breathlessness during progressive exertion in patients with chronic obstructive lung disease.

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