

Blood lactate and respiratory muscle fatigue in patients with chronic airways obstruction

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ABSTRACT Blood lactate concentrations were measured in five patients with chronic airways obstruction after 10 minutes' sustained maximal voluntary ventilation (SMVV) with end-tidal carbon dioxide tension kept constant and after a 12-minute walk. No patient showed a significant rise in blood lactate after SMVV but all showed evidence of low-frequency fatigue of the sternomastoid muscle. After a 12-minute walk three patients showed a significant rise in blood lactate and two of them also had evidence of low-frequency fatigue of the sternomastoid muscle. The absence of a rise in blood lactate after SMVV may be due to the fact that in patients with chronic airways obstruction ventilation is limited by airflow obstruction to a level where only a small muscle mass is used, or where the aerobic capacity of the respiratory muscles is not exceeded.

We have shown previously in normal subjects that sustained maximal voluntary ventilation (SMVV), with end-tidal carbon dioxide tension (PCO_2) kept constant, raises the blood lactate concentration by a mean of 1.5 mmol/l (13.5 mg/100 ml).¹ We postulated that when patients with chronic airways obstruction performed SMVV the rise in lactate would be the same as or greater than in normal subjects because they are achieving levels of ventilation that are the same as or greater than those of normal subjects in relation to their maximum breathing capacity. We were interested to correlate changes in lactate with physiological evidence of muscle fatigue. We have previously shown that exercise produces low-frequency fatigue of the sternomastoid muscle in such patients² and we have therefore compared changes in lactate concentrations with sternomastoid force frequency curves³ before and after both SMVV and a 12-minute walk in patients with chronic airways obstruction.

Methods

The five patients with chronic airways obstruction (all men) were attending outpatient clinics and were aware of the nature and purpose of the investigation and gave verbal consent. Each patient was studied on three separate occasions.

In experiments using SMVV the patients breathed as hard as possible for 10 minutes. The equipment

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and method used for the SMVV have been described previously.¹ We used the circuit described by Eger *et al.*,⁴ in which carbon dioxide is continuously added at a rate controlled by the experimenter to maintain an end-tidal carbon dioxide tension (PCO_2) at any desired level. Oxygen was also added continuously at a rate of about 12 l/min during the SMVV. The experiments were carried out with the patients in the sitting position. Lactate and pyruvate concentrations were measured in 1–2 ml of venous blood, which was immediately transferred into pre-weighed tubes containing ice-cold perchloric acid, with which the samples were thoroughly mixed. They were analysed by the method of Lloyd *et al.*⁵ The coefficients of variation for repeat measurements were 3% for lactate and 11% for pyruvate.

The 12-minute walking distance was measured by the method of McGavin *et al.*⁶ The method used for producing the force frequency curve of the sternomastoid muscle has been described previously³; three curves were obtained on each occasion. Standard spirometry was carried out on all patients with Floop apparatus (Oldeft).

The protocol for the study was as follows. On the first visit baseline spirometric values and three sternomastoid force frequency curves were obtained. Two resting venous blood samples were taken for pyruvate and lactate estimations. Each patient then did a 12-minute walk. A venous blood sample was taken at the end of this and further sternomastoid force frequency curves were obtained five minutes after the end of the walk. The distance walked and

the heart rate during the first 15 seconds of recovery were recorded. On a second visit patients walked for 12 minutes on a treadmill, the speeds being such that each patient covered the same distance as during the initial 12-minute walk. On this occasion we measured each patient's heart rate continuously and his ventilation during the last two minutes of exercise.

On the third visit spirometric measurements and sternomastoid force frequency curves were again obtained and two resting venous blood samples were drawn for pyruvate and lactate estimations. Each patient then performed an SMVV for 10 minutes. No target was set but the patients were asked to breathe as hard as possible for the 10 minutes, and encouragement was given. Immediately after the SMVV a venous blood sample was taken for lactate and pyruvate estimations and the sternomastoid force frequency curves were repeated five minutes later.

Results

Details of the patients and measurements of ventilation are given in table 1. The heart rates at the end of the 12-minute walk and during the final minute of the treadmill walk were almost identical in all patients, with means of 131.2 ± 7.3 and 128 ± 6.1 beats/min respectively. This indicates that the physiological stress of the treadmill walk was a reasonably close approximation to that of the 12-minute walk. The distances covered during the 12-minute walk (table 1) show that all the patients were moderately disabled.

The ventilation achieved during the SMVV is a mean for the 10 minutes for each patient and is expressed as a percentage of each patient's maximum breathing capacity (MBC), calculated from the formula $MBC = (FEV_1 \times 18.9) + 19.7$.⁷ The maximal ventilation during the treadmill walk is also expressed as a percentage of the predicted maximum breathing capacity for each patient. The average ventilation of the five patients during both the

SMVV and the treadmill walk was close to 70% of the maximum breathing capacity. Although there were quite large individual variations, there were no significant differences in the ventilation achieved during the SMVV and the treadmill walk (paired *t* test).

Average resting blood lactate concentrations were 1.23 mmol/l with a range of 0.65–1.79 mmol/l (11.08 and 5.86–16.13 mg/100 ml) before the 12-minute walk and 0.98 mmol/l with a range of 0.55–1.95 mmol/l (8.83 and 4.95–17.57 mg/100 ml) before SMVV. Table 2 shows for each patient the change in blood lactate concentration from resting values produced by the 12-minute walk and SMVV. It also indicates whether low-frequency fatigue of the sternomastoid muscle was present after each of these tests. Four patients developed low-frequency fatigue of the sternomastoid after the 12-minute walk, and three patients had a significant increase in blood lactate concentration of more than 1 mmol/l (9.0 mg/100 ml). After SMVV all patients had low-frequency fatigue of the sternomastoid, but no patient had a significant increase in blood lactate. There were no correlations between ventilation (either in absolute terms or as a fraction of maximum breathing capacity) and blood lactate concentration. End-tidal PCO_2 was easily kept in the range 4.9–6.1 kPa (37.0–45.5 mm Hg) in all patients during SMVV (table 2). There was no significant change in pyruvate concentration in any patient, even after the 12-minute walk.

Discussion

We have shown that none of the patients with chronic airways obstruction showed a rise in blood lactate concentration after SMVV; yet normal subjects have been shown to raise their blood lactate by a mean of 1.5 mmol/l (13.5 mg/100 ml) after 10 minutes' SMVV with normal PCO_2 ,¹ and the technique of measuring SMVV was identical in both this previous study and the present one. This result is at first sight surprising, especially when both the

Table 1 Details of the patients and their ventilation levels during exercise

Patient No	Age (y)	FEV ₁ (l)	Predicted MBC (l/min)	Distance covered during 12-minute walk (m)	Treadmill walk $\dot{V}E$ (% MBC)	SMVV mean $\dot{V}E$ (% MBC)
1	65	1.30	44.3	1200	76	76
2	63	0.86	35.9	1200	96	55
3	60	0.72	33.3	900	76	57
4	60	1.19	42.2	1000	84	70
5	67	1.34	45.0	900	73	92

FEV₁—forced expiratory volume in one second; MBC—maximum breathing capacity; $\dot{V}E$ —minute ventilation; SMVV—sustained maximal voluntary ventilation.

Table 2 Change in lactate concentrations and presence of low-frequency fatigue of the sternomastoid muscle (LFFSM) produced by a 12-minute walk and sustained maximal voluntary ventilation (SMVV)

Patient No	12-minute walk		SMVV		
	Δ Lactate (mmol/l)	LFFSM	Δ Lactate (mmol/l)	LFFSM	Range of end-tidal PCO_2 during SMVV (kPa)
1	+ 1.27	+	+ 0.03	+	5.0–5.5
2	+ 1.38	-	- 0.04	+	5.1–5.9
3	- 0.46	+	+ 0.13	+	4.9–5.8
4	- 0.14	+	+ 0.01	+	5.7–6.1
5	+ 1.53	+	+ 0.22	+	5.7–6.0

Conversion: SI to traditional units—Lactate: 1 mmol/l ≈ 9.0 mg/100 ml; carbon dioxide tension (PCO_2): 1 kPa = 7.5 mm Hg.

patients and the normal subjects had equivalent relative ventilations in terms of percentage of maximum breathing capacity. Our patients were older than our normal subjects, but if anything one might expect increased anaerobic metabolism after exercise with increasing age. In patients with chronic airways obstruction expiratory flow at all lung volumes is limited to low levels by the state of the airways and quite modest pleural pressures are required to generate these flows. Leaver and Pride^{8,9} have shown that during exercise these patients do not waste muscle force in developing inappropriately large expiratory pleural pressures but they develop the minimum pressure necessary to achieve maximum flow—that is, they use their respiratory muscles in the most economical way. If patients were to breathe in a similarly economical way during SMVV it might explain the absence of a rise in lactate after SMVV in patients with chronic airways obstruction. In normal subjects estimates of the mass of the respiratory muscles suggest that some of the increase in lactate after SMVV is coming from other muscle groups—namely, abdominal and trunk muscles.¹ Owing to limitation of ventilation by airflow obstruction patients with chronic airways disease may not have used as many muscle groups as normal subjects during the SMVV.

We presume that hypoxia would have been a more important factor in patients with chronic airways obstruction than in normal subjects and thus the absence of a change in blood lactate concentration after SMVV is even more surprising. There was no correlation between the rise in the blood lactate during these physiological stress tests and the presence of low-frequency fatigue of the sternomastoid muscle. This suggests either that the muscle is too small to contribute significantly to any change in blood lactate or that low-frequency fatigue can develop in the absence of sustained anaerobic metabolism.

Our findings do not support those of Belman and Mittman,¹⁰ who showed that patients with chronic airways obstruction have a rise in blood lactate after SMVV. In their study no details were given of

whether PCO_2 was kept within the normal range during the SMVV. There would appear to be no previous data on changes in blood lactate concentration after a 12-minute walk in patients with chronic airways obstruction. Three patients showed a significant rise in blood lactate after the walk and we presume that this is due to anaerobic metabolism of the leg muscles.

We conclude that patients with chronic airways obstruction breathe hard enough to produce low-frequency fatigue of the accessory muscles during exercise and SMVV but do not stress the respiratory muscles enough to produce evidence of anaerobic metabolism.

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