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Rapid communication

pH after competitive rowing: the lower physiological range?

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At rest, pH is one of the most stable physiological variables with an average of 7.41 (range 7.38–7.44) corresponding to a $[H^+]$ of 39 nmol kg^{-1} H_2O. Yet, in both health and disease, pH decreases in response to hypoventilation and especially to anaerobic metabolism when 'acid production' exceeds the buffer capacity. Thus, blood pH is below 7.1 in diabetic ketoacidosis (Snorgaard *et al.* 1989) and in response to maximal exercise involving a large muscle mass (Rasmussen *et al.* 1991), the average value is 7.1. Blood pH may be even lower during a competitive physical effort as blood lactate is higher than during exercise in the laboratory (11 vs. 17 mmol L^{-1}) (Vaage 1986). However, in healthy humans, the lower physiological limit of pH is not known. This study investigated pH of venous blood immediately after the Danish ergometer rowing championship.

Six male oarsmen [age 30 ± 1 year, body weight 78 ± 2 kg, height 186 ± 3 cm, maximal oxygen uptake 5.2 ± 0.2 L min^{-1} (mean ± SEM)] participated in a '2000-m' maximal effort on a rowing ergometer (Concept II, type C; Dreisacker, Morrisville, VT). Two of the oarsmen had won an Olympic gold medal (Atlanta), two were lightweight World champions, and two rowers ranked at the National level. Within 2 min of termination of rowing, a venous puncture was made in an arm vein allowing for free flow. Blood (1 mL) was obtained in a heparinized syringe and measured on a ABL615 apparatus (Radiometer, Copenhagen, Denmark). Plasma lactate was measured in triplicates (YSI 2300; Yellow Springs Instruments, OH, USA) with the average value presented.

The concentration of lactate in venous blood was elevated and reached an upper level of 32 mmol L^{-1} (Table 1). In all rowers, pH was reduced immediately after exercise and the lowest value (6.74) was measured in one of the Olympic gold medalists who won the Danish championship of the lightweight class in a World record time (6 min, 04 s). The second lowest pH (6.76) was measured in one of the rowers who ranked at the National level. Furthermore, base excess and bicarbonate were lowered and in the two subjects with the lowest pH, bicarbonate was not detectable. All oarsmen remained conscious after rowing, and there was no indication for medical interference.

A low pH affects the affinity of haemoglobin to O_2. During exercise O_2 saturation of haemoglobin (S_aO_2) decreases to 93% (Nielsen *et al.* 1998) as arterial O_2 tension (P_aO_2) is reduced (Dempsey *et al.* 1984) and hypoxaemia hinders O_2 uptake (Powers *et al.* 1989, Nielsen *et al.* 1998). During competitive exercise, haemoglobin affinity to O_2 may be lower. A pH of 6.74 at the P_aO_2 obtained during ergometer rowing (Nielsen *et al.* 1998), S_aO_2 would be reduced to 78% (Severinghaus 1958). A reduction in S_aO_2 from 97 to 78% would in turn affect O_2 uptake by ≈15% (Nielsen *et al.* 1998) as cardiac output does not compensate for a decrease in S_aO_2.

pH was related to a high blood lactate level and a marked reduction in bicarbonate. A pH of 6.74 corresponds to $[H^+]$ of 182 nmol kg^{-1} H_2O which is more than a fourfold increase compared with the value at rest and twice than that previously reported during maximal exercise (Rasmussen *et al.* 1991, Nielsen *et al.* 1998). As bicarbonate was undetectable and lactate twice than

Table 1 Acid–base balance in blood after maximal exercise

	pH	Lactate (mmol L^{-1})	SBC (mmol L^{-1})	SBE (mmol L^{-1})
Rest	7.42 ± 0.01	0.6 ± 0.1	25.2 ± 0.6	0.8 ± 0.7
Exercise	6.85 ± 0.04	26.2 ± 1.6	6.0 ± 1.9	−17.3 ± 1.3

Values are mean ± SEM at rest and during maximal rowing. SBC, standard bicarbonate; SBE, standard base excess. Resting values are from Nielsen *et al.* (1998)

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that measured immediately after an on-water European champion race (Vaage 1986), a pH of 6.74 may be considered to be close to the lowest physiological range. In healthy humans, pronounced, but transient, acidosis is well-tolerated.

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