

**METABOLIC AND PHYSIOLOGICAL RESPONSES TO SUBMAXIMAL  
INTERMITTENT EXERCISE IN NEONATAL LAMBS**

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**SUMMARY**

Eight Merino lambs were studied before, during and after 3 five-min exercise bouts on a motor driven treadmill at 1 m/s. Selected physiological effects were measured and blood collected concurrently by venipuncture. Exercise produced over a two-fold increase in oxygen uptake as well as significant elevations in rectal temperature, respiratory rate, and blood lactate and pyruvate concentrations. These increased levels returned to resting values within 30 min after exercise. By contrast, no significant changes occurred in heart rate, blood glucose, total protein or free fatty acids during exercise. The behaviour of the lambs was not affected by the test procedure. The metabolic and physiological responses observed during intermittent exercise, suggest that anaerobic processes play only a minor role in energy supply.

**INTRODUCTION**

Neonatal lambs often follow their mothers at walking pace interspersed with submaximal running as the ewes move away from the birth sites in search of food and water. The lambs sometimes undergo short spells of exhaustive running in response to the mothers' bleats if they are separated or at the approach of predators. Some studies have been undertaken to evaluate substrate utilization and physiological changes in farm animals during work (Faraci et al. 1984; Kuhlmann et al. 1985), but no such information is available for neonates. The aim of the present investigation was to measure the effects of short periods of moderate exercise on metabolic and physiological parameters as a guide to understanding energy metabolism and responses to stress during normal running activities in neonatal lambs.

**MATERIALS AND METHODS**

Eight healthy single-born Merino lambs, with a live weight of  $5.89 \pm 0.26$  kg (s.e.m.), were used in this study. The lambs were born and held outdoors prior to testing.

At approximately 48 h post partum each lamb was weighed and confined with its mother in a pen in a temperature controlled room at 25°C for a minimum time of 30 min. The lamb was then fitted with a lightweight plastic mask attached behind the ears by means of a velcro clasp and held on the lap of an observer for about 15 min, during which time resting state physiological measurements and blood samples were taken. The lamb was then placed on a motor driven treadmill, with the mother in a cage facing it, and was subjected to 3 five-min exercise bouts at 1 m/s separated by 2 three-min rest pauses followed by 30 min recovery period. Physiological measurements were taken simultaneously, followed by blood sampling at the end of each exercise bout, and at five, 15 and 30 min after discontinuation of exercise,

Metabolic rate or oxygen uptake rate ( $\text{VO}_2$ ) was measured continuously during rest and exercise periods by means of an open-flow method similar to that described by Seeherman et al. (1981), and expressed as  $\text{ml O}_2/\text{s/kg}$  live weight (STPD). Rectal temperature as an indicator of body temperature was measured

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using a calibrated thermocouple with a digital display. Heart rate was taken from an electrocardiogram (ECG) by electrodes inserted into the skin, and a fine copper-constantan thermocouple taped across a nostril of the lamb indicated respiratory rate. Both outputs were displayed on a dual channel chart recorder (Duograph; Gilson Medical Equipment).

Blood samples obtained by jugular puncture were put into tubes coated with EDTA and immediately placed in ice. One ml of blood was deproteinised by addition of equal volume of 8% perchloric acid, the mixture was centrifuged and the supernatant used for estimation of glucose (Bergmeyer and Bernt 1974b), lactate (Gutmann and Wahlefeld 1974) and pyruvate (Bergmeyer and Bernt 1974a). Plasma levels of free fatty acids (FFA) (Boehringer, Mannheim diagnostic kit) and total protein (Sedmak and Grossberg 1977) were also determined.

Differences between means of resting and exercise data were examined by Student t-tests for paired data. Regression analysis was used to test for significant correlations between parameters. Values are presented as means  $\pm$  s.e.m.

### RESULTS

The lambs fell into a relaxed state within three to five min of being placed on the lap of an observer for resting measurements. During treadmill exercise the ewe often stood up in the cage with her head close to the treadmill and bleated intermittently. The lamb's bleating response to the mother's call ceased or reduced considerably on achieving steady state running. The exercise did not seem to affect the behaviour of the lambs and no detrimental effects resulting from the experimental procedure were subsequently observed.

Table 1 Metabolic effects of intermittent exercise

|                | Lactate<br>(mM) | Pyruvate<br>(mM) | Glucose<br>(mM) | Protein<br>(ug/l) | FFA<br>(mM) | O <sub>2</sub> Uptake<br>(ml/s/kg) |
|----------------|-----------------|------------------|-----------------|-------------------|-------------|------------------------------------|
| Rest           | 1.08            | 0.073            | 5.16            | 79.5              | 0.341       | 0.320                              |
| Exercise bout  |                 |                  |                 |                   |             |                                    |
| 1              | 1.60*           | 0.095*           | 5.21            | 76.2              | 0.371       | 0.757***                           |
| 2              | 1.73**          | 0.110**          | 5.02            | 79.9              | 0.357       | 0.768***                           |
| 3              | 1.97***         | 0.110*           | 4.94            | 79.0              | 0.302       | 0.679***                           |
| Recovery (min) |                 |                  |                 |                   |             |                                    |
| 5              | 1.68*           | 0.105            | 4.78            | 75.9              | 0.314       |                                    |
| 15             | 1.36*           | 0.080            | 5.09            | 82.7              | 0.285       |                                    |
| 30             | 1.12            | 0.071            | 5.31            | 81.4              | 0.319       |                                    |

Significantly different from resting values, P<0.05\*; P<0.01\*\*; P<0.001\*\*\* (Paired t-test).

Metabolic changes during the interval exercise are shown in Table 1. Blood lactate and pyruvate concentrations in the lambs increased progressively (P<0.05 - 0.001) during the exercise bouts, then gradually returned towards resting values. The changes in the two metabolites were highly correlated ( $r=0.96$ , P<0.001). With the exception of one lamb which had an increase in blood lactate concentration extending into the first five min of recovery, lactate concentration in all others decreased gradually after exercise and had returned to resting values by the end of the recovery period (Fig. 1). Lactate concentrations remained high during the first five min after exercise in the two lambs showing the highest concentration during exercise. Blood pyruvate concentration on the other hand reached a plateau during the second and third exercise bouts; the decrease after exercise to resting value was rapid. There were no significant changes in blood glucose nor in plasma total protein and FFA concentrations during exercise and recovery periods.

Oxygen uptake increased 2.4 fold over the resting value during the first exercise bout to approximately 60% of the previously determined maximal oxygen uptake and remained significantly elevated ( $P < 0.001$ ) during subsequent bouts. The exercise on average elicited  $0.366 \pm 0.028$  ml  $O_2$ /kg/stride. The lambs ran at an overall stride frequency of  $1.80 \pm 0.07$  per second at  $0.57 \pm 0.02$  cm per stride.

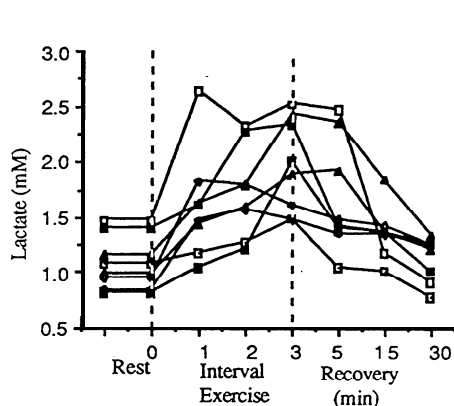


Fig. 1. Blood lactate effects of exercise

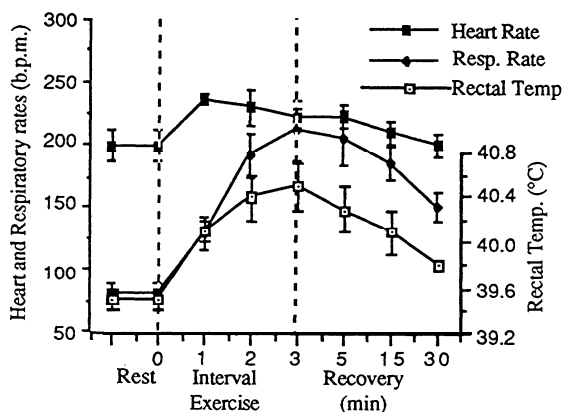


Fig. 2. Physiological effects of exercise

Fig. 2 illustrates changes in physiological parameters during exercise and recovery. The changes in heart rate during exercise, though substantial were not statistically significant. Respiratory rate increased progressively to a maximum of 2.6 fold over the resting value to  $211 \pm 23$  breaths/min during the last exercise bout. The rate thereafter decreased to  $150 \pm 11$  breaths/min at 30 min after exercise. The observed respiratory rates during exercise and recovery were significantly different from resting values ( $P < 0.001$ ). Rectal temperature at rest,  $39.5 \pm 0.1^\circ\text{C}$ , was significantly elevated ( $1.0^\circ\text{C}$ ,  $P < 0.001$ ) by the end of the exercise, and was followed by a progressive fall to  $0.3^\circ\text{C}$  above resting value at the end of recovery period. Rectal temperature correlated significantly with respiratory rate ( $r = 0.93$ ,  $P < 0.001$ ) during exercise and recovery.

#### DISCUSSION

The similar patterns of blood lactate and pyruvate evolution during exercise and recovery were consistent with the observations in humans by de Coster et al. (1969). During exercise of moderate intensity with adequate rest pauses, as in the present study, there was no or only a slight increase in blood lactate concentration (Christensen et al. 1960). The extension of lactate and pyruvate elevations into the first five min of recovery in some of the lambs may be attributed to the significantly higher metabolic rates exhibited during the exercise resulting in increased post exercise metabolism.

The plasma FFA response to exercise in the present study differed from those previously reported in humans where a marked rise occurred during mild intermittent exercise followed by a gradual fall (Kuel et al. 1974). Insignificant changes in blood glucose in this study support the assertion that clearance in blood glucose is only seen during exercise of longer duration (Keeper et al. 1969). The plasma total protein concentrations were not

affected by the exercise since the duration of work performed was neither long enough nor the intensity high enough to demand the use of protein sources of energy.

The body temperature response to intermittent exercise observed in humans by Christensen *et al.* (1960) is similar to the significant elevation in rectal temperature observed in the present study. Both values were higher than the 0.3°C rise reported in calves subjected to exhaustive exercise (Kuhlman *et al.* 1967). The progressive rise in rectal temperature during the exercise bouts in the present study while  $\text{VO}_2$  remained at a steady level suggests insufficiency of the lambs thermoregulatory mechanisms to dissipate totally the metabolic heat produced.

The increases in heart rate over the resting values (11-18%) during the exercise were lower than the increase (113%) observed in human subjects during mild intermittent exercise at 50% but similar to values determined at 25% aerobic capacity (Edwards *et al.* 1973). The rather high respiratory rate in lambs during the intermittent exercise compared with those subjected to cold induced summit metabolism (Alexander and Bell 1975) may be attributed to the different muscle systems involved in the two tests.

The metabolic and physiological effects of the intermittent exercise, especially the small changes in heart rate, blood lactate and pyruvate concentrations, confirm that the work imposed on the lambs during the exercise was at a submaximal level, and suggest that most running activities in neonatal lambs are undertaken by utilizing primarily aerobic pathways, with only minor contribution from anaerobic pathways of metabolism.

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