

Reindeer breathe less and save water in the cold

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Abstract: Simultaneous measurements of metabolic rate, respiratory minute volume, respiratory frequency, and oxygen extraction from the inspired air were obtained during treadmill exercise in Svalbard reindeer (*Rangifer tarandus platyrhynchus*) and Norwegian reindeer (*Rangifer tarandus tarandus*). The experiments were carried out both in summer and winter at ambient temperatures and running speeds ranging from +12 to -30°C and 3.7 to 9.0 km·h⁻¹, respectively. We found that respiratory minute volume was generally lower in summer than in winter for a similar ambient temperature, and also that respiratory minute volume was reduced at low ambient temperature both in summer and winter. The change in respiratory minute volume was inversely related to oxygen extraction, the latter being at its highest at the lowest ambient temperature and running speed in summer. Reduction of respiratory minute volume, and hence respiratory water loss, at low ambient temperature is likely to contribute significantly to the survival of these species, particularly in winter when the animals can only replace body water with snow at low temperature.

Key words: *Rangifer tarandus*, temperature regulation, oxygen extraction, arctic

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Introduction

The Svalbard reindeer and the Norwegian reindeer both survive under the most austere nutritional conditions in the arctic and sub-arctic regions, where energy conservation is a matter of supreme importance. In winter, ambient temperature often rises above freezing fol-

lowed by long periods of bitter cold. Such weather produces a crust of ice which severely limits the animals access to the already poor winter range. Thus, with plant quality as well as availability much reduced, energy economy attains a substantial survival value. To that end both the Svalbard and the Norwegian reindeer

are equipped with fur of unsurpassed quality during winter, while respiratory heat and water loss are reduced by nasal heat exchange in the resting reindeer (Blix and Johnsen, 1983; Johnsen, *et al*, 1985a).

Since oxygen consumption, and hence heat production, is largely independent of variations in ambient temperature in the exercising reindeer (Nilssen, *et al*, 1984), the overall oxygen extraction in the lungs must be altered in accordance with the changes in minute volume that are normally associated with variations in thermal load. In order to elucidate further the respiratory adjustments which are accompanied by variation in thermal load, we have measured simultaneously respiratory minute volume, respiratory frequency, and oxygen extraction in exercising Svalbard and Norwegian reindeer subjected to different ambient temperatures in winter, when fur insulation is prime, and in summer when fur insulation is at its minimum.

Methods

Two adult female Svalbard reindeer (*Rangifer tarandus platyrhynchus*) and two adult female Norwegian reindeer (*Rangifer tarandus tarandus*) were used in this study. Between experiments the animals were kept outdoors at the Department of Arctic Biology, University of Tromsø, where food (RF-71; Jacobsen and Skjenneberg, 1979) and water and snow were available *ad libitum*.

The experiments were carried out in a climatic chamber at temperatures of -24 and +12°C in summer (late July) and -30 and +9°C in winter (February and March). Thus, the summer values were obtained with fur insulation at a minimum, while the winter values were obtained with fur insulation at its prime. The temperature of the chamber was controlled within $\pm 1^\circ\text{C}$ in time and $\pm 2^\circ\text{C}$ in space with a constant wind speed of $0.6\text{ m}\cdot\text{s}^{-1}$. Barometric pressure inside the chamber was the same as outdoors.

The climatic chamber contained a 3.5 m long and 1.0 m wide level treadmill driven by a variable-speed motor providing constant speed regardless of load. The noise level inside the chamber was 63 dB (A) when the treadmill was running at $9\text{ km}\cdot\text{h}^{-1}$. The animals were accustomed to run fully instrumented on the treadmill over a period of 6 months before any measurements were made.

For calculations of respiratory minute volume and oxygen consumption the animals expired into an airtight face mask with two one-way valves, with the outlet valve connected to a 150 liter spirometer. The system was arranged in such a way that the mask could be connected to the animal while it was running. After a sample of air was obtained the air was dried before it was passed through an O_2 -analyser (Model S-A, Applied Electrochemistry, California, USA) and a CO_2 -analyser (Model Binos 1, Leubold Heraus GmbH, Hanau, West Germany) for measurements of O_2 and CO_2 concentrations, respectively. Respiratory frequency was calculated by use of a thermocouple fixed into one of the valves, monitoring changes in temperature associated with changes in air-flow direction.

Rectal temperature was obtained by use of a copper/constantan thermocouple inserted 15 cm into the rectum and connected to a Fluke 2190A digital thermometer (accuracy $\pm 0.1^\circ\text{C}$).

During experiments the animals were allowed a 60 min equilibration period before exercise began. After 5 min of exercise, when O_2 -consumption and CO_2 -production had reached equilibrium, the airtight mask was connected to the animal and approximately 100 liters of air was collected. Based on this air sample values for respiratory minute volume, respiratory frequency, tidal volume, metabolic heat production and oxygen extraction were determined. Oxygen extraction was calculated as the percentage partial pressure of oxygen in the inspired air minus that of the expired air.

All volumes have been converted to STPD,

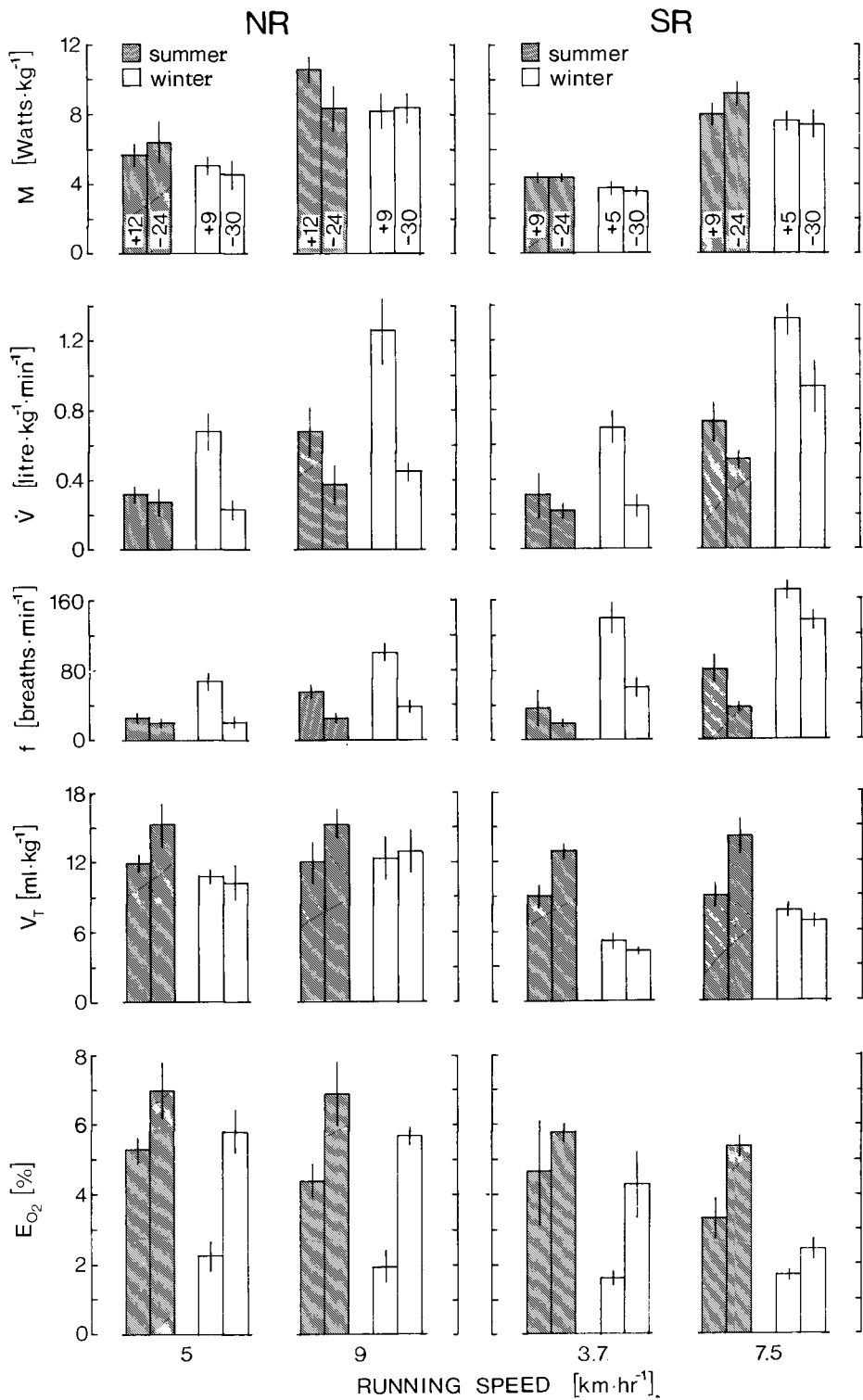


Fig.1. Simultaneous measurements of metabolic rate (M), respiratory minute volume (\dot{V}) respiratory frequency (f), together with calculated values for tidal volume (V_T) and oxygen extraction E_{O_2} , in Norwegian (NR) and Svalbard reindeer (SR). The values were obtained at various ambient temperatures (indicated within the columns of the top panel) and running speeds both in summer and winter.

and a caloric equivalent of $20.17 \text{ J}\cdot\text{mlO}_2^{-1}$ have been used for calculation of heat production.

Results

The results from both the Norwegian reindeer and the Svalbard reindeer are presented in Fig. 1. The values for metabolic heat production have been presented in a previous paper (Nilsen *et al.*, 1984).

In general, respiratory minute volume was higher in winter as compared to summer for a similar ambient thermal load, but lower at low, as compared with high, ambient temperature within the same season. Reduction of respiratory minute volume in response to cold was especially pronounced at low ambient temperature and running speed in the winter insulated animal. Reduction of respiratory minute volume in response to low ambient temperature was predominantly due to reduced respiratory frequency accompanied by increased tidal volumes in the Svalbard reindeer, but not in the Norwegian reindeer. It appeared, however, that tidal volume at the lowest ambient temperature in summer was elevated in both the Svalbard and the Norwegian reindeer, regardless of running speed.

Reduction of respiratory minute volume in response to cold was always accompanied by a significant ($p < 0.001$) increase in oxygen extraction in both Svalbard and Norwegian reindeer (Fig. 1). This relationship is illustrated in Fig. 2.

Discussion

Previous studies in reindeer indicate that respiratory heat loss is low at low ambient temperatures, both during rest (Blix and Johnsen, 1983) and during short periods of exercise (Folkow and Mercer, 1986; Johnsen *et al.*, 1985b). The present results support this view and suggest that respiratory minute volume and frequency, and hence respiratory water and heat loss, are low during exercise at low ambient temperature both in winter and in summer

(Fig. 1). Reduction of respiratory minute volume was always accompanied with an increase of oxygen extraction from the inspired air. Our results in exercising reindeer are consistent with previous observations in resting sheep (Joyce and Blaxter, 1964) and pigs (Ingram and Legge, 1969/70) which respond to cold stress by increased oxygen extraction.

The increased oxygen extraction observed

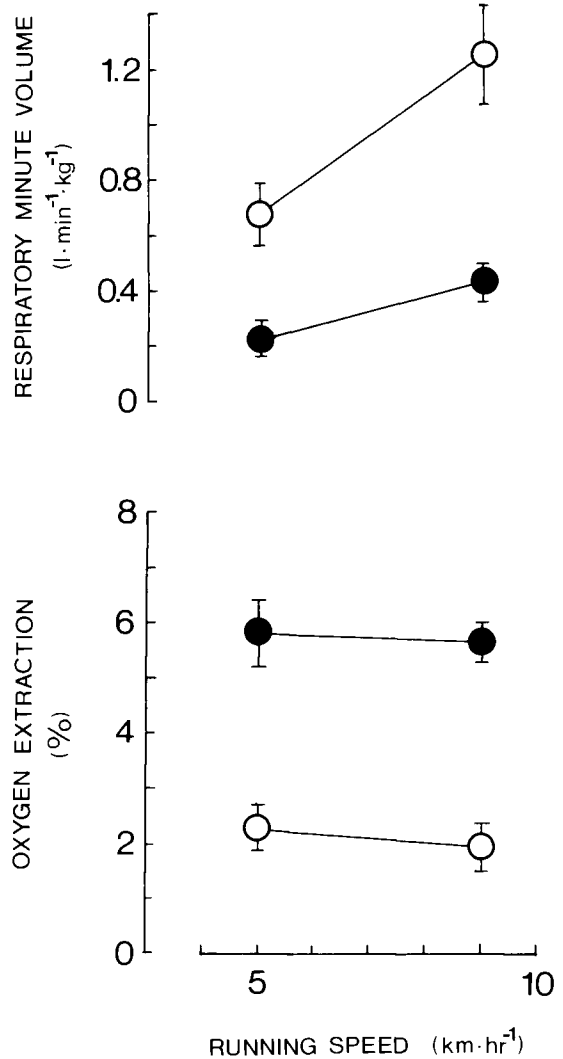


Fig. 2. Respiratory minute volume and oxygen extraction in relation to running speed in Norwegian reindeer. The values were obtained in winter at ambient temperatures of +9 (open circles) and -30°C (filled circles).

during exercise at low ambient temperatures in the reindeer may, at least in part, be explained by an increase in tidal volume (Fig.1), but a combination of respiratory and circulatory adjustments, such as those described by Bech *et al.* (1984) in the pekin duck (*Anas platyrhynchos*), may also contribute to this end.

We suggest that reduction of respiratory minute volume, and hence respiratory water loss, in response to cold contribute significantly to the survival of reindeer, both at rest and during running. This would be particularly important in winter when the animal has to replace body water with snow at low temperature.

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