

INHALATION REWARMING FROM HYPOTHERMIA:

An evaluation in -20°C simulated field conditions

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INTRODUCTION

Inhalation of warm oxygen or air saturated with water vapour has been demonstrated to enhance the rate of core temperature increase and minimize the magnitude of the initial post-exposure decrease in core temperature ('after-drop'), which is usually associated with recovery from hypothermia (Golden and Hervey, 1981). Initially proposed by Lloyd and co-workers (Lloyd et al. 1972; Lloyd, 1973), this method of active core rewarming has now become a recommended method of pre-hospital management of hypothermia victims (American Heart Association; Harnett et al., 1983a,b). With the exception of the study by Sterba (1991), who examined the efficiency of the method at 2°C, all evaluations to date have been conducted at normal room temperatures.

At sub-zero ambient temperatures (-20°C), simulating extreme field conditions, respiratory heat loss is greatly exaggerated. We hypothesized that under such conditions the benefit of inhalation rewarming is not just from the delivery of heat to the respiratory tract, but also from the elimination of respiratory heat loss. Accordingly, we compared the rate of rewarming of hypothermic subjects in a -20°C ambient, using three methods of rewarming: a) passive rewarming, b) inhalation rewarming using the Heat Treat®, and c) passive rewarming with a prototype respiratory heat and moisture exchanger, which reduced respiratory heat loss.

METHODS

Ten healthy male subjects participated in the study, which received prior approval by the institutional Ethics review process. Subjects' mean (SD) age, height and weight were 29 (5) yrs., 176 (6) cm, and 71 (9) kg., respectively.

Wearing only bathing attire, subjects were immersed in 15°C water for 60 min., or until their rectal temperature (Tre) decreased to 35°C or by 1.5°C from pre-immersion values. After this cooling period, they were removed from the tank, towed dry, and positioned on a stretcher in an assembly of insulated bags: the inner bag was a water impermeable bag, the intermediate bag was an insulated sleeping bag rated for -20°C, and the outer bag was also an insulated sleeping bag rated for +10°C. They were then transferred into a climatic chamber maintained at -20°C, and remained in the chamber for 2 hours. With the exception of the quality of the inspired air, all trials had an identical protocol.

1. **Control trial:** Subjects inspired room air.

2. **Heat Treat® trial:** Subjects inspired air from a Heat Treat® device situated external to the chamber. The device contains a water reservoir heated by propane, through which inspired air is drawn, and thus heated and saturated with water vapour. The air was delivered to the subject via respiratory tubing.

3. **HME trial:** Subjects breathed through a passive heat and moisture exchanger (HME). The prototype comprised a thermally insulated oro-nasal mask with a cylindrical heat exchange unit protruding from the centre of the mask. The "honeycomb" aluminum structure contained approximately 300 honeycomb-shaped cells, which provided a total surface area of 478.5 cm² for heat and moisture exchange.

During the cooling and rewarming period, subjects' rectal temperature (Tre) was monitored at minute intervals with a YSI 701 (Yellow Springs Instruments) rectal thermistor probe inserted 5 cm. Skin temperature was monitored at four sites (arm, chest, thigh, and calf) with T-type thermocouples. The temperature within the oro-nasal mask was also monitored with a T-type thermocouple probe. Data were recorded using an HP3497A Data Acquisition System (Hewlett Packard).

RESULTS

During the rewarming period, there was no significant difference in skin temperature (T_{sk}) response between the three conditions. The ambient temperature and thus the inspired air temperature in the control condition was -19.4 (1.1) °C. The temperature within the oro-nasal mask was +20.5 (1.2) °C in the HME trials and +36.2 (2.9) °C in the Heat Treat® Trials.

The efficiency of the HME and Heat Treat® were assessed by comparing the Tre responses in these trials with the response observed during the control condition. Due to the *a priori* decision to include in the analysis only the Tre responses of subjects who exhibited a decrease in Tre greater than 1°C during the cooling period, 2 of the 10 subjects were excluded from the analysis. The average Tre response (N=8) during the rewarming period in the control condition exhibited a significant (p<0.05) decrease in Tre (afterdrop). In contrast, the post-immersion decrease in Tre was not significant in the HME and Heat Treat® trials. There were no significant differences in the rates of rewarming in the three conditions. In all

three conditions, the average Tre was significantly lower compared to pre-immersion values, indicating that complete rewarming had not been achieved.

CONCLUSIONS

The results demonstrate that in sub-zero temperatures, the Heat Treat@ does not enhance rewarming rate in conscious shivering subjects. However, it reduces the magnitude of the post-exposure drop in Tre, but this effect may be attributed to a reduction in respiratory heat loss, rather than a donation of heat to the respiratory tract. This was confirmed by the similar Tre responses during rewarming observed when subjects were rewarmed passively, while respiratory heat loss was minimized by use of a heat and moisture exchanger. The results also suggest that the Tre rewarming responses observed in laboratory studies over-estimate the rates of rewarming that would commonly be observed during rewarming in the field.

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