PREDICTING THE USEFULNESS OF COLD GAS BREATHING FOR REDUCING HEAT LOAD DURING WARM WATER DIVING

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With military diving operations in the warm waters of the Middle East as well as commercial diving operations in nuclear reactor coolant pools and contaminated water, the problems of heat stress in diving have become a concern. This paper explores the utility of manipulating the density, specific heat, and inspired gas temperature of the breathing mixture to increase respiratory heat loss (H_{Resp}) and reduce heat load during extended diving missions in warm water. In the absence of a specific study investigating H_{Resp} during warm water diving conditions, data from several sources in the open scientific literature were used to predict H_{Resp} during shallow warm water diving conditions. Oxygen consumption ($\dot{V}O_2$) and minute ventilation ($\dot{V}_E$) were obtained for US Navy divers performing underwater bicycle exercise in 34.4°C while breathing air from a demand regulator at 20 fsw (Doubt and Dukta, 1990). Body heat production was determined by converting $\dot{V}O_2$ to Watts and subtracting the external work. Predictions of H_{Resp} were calculated for warm (31°C) and cold (1°C) air, normoxic helium (heliox), and normoxic SF6 gas mixtures while at rest and during light (50 W) and moderate (105 W) underwater exercise. Respiratory heat loss for breathing heliox at the two inspired gas temperatures was derived using the linear regression equations of H_{Resp} versus $\dot{V}_E$ described by Hoke *et al.*, (1976). These heliox data were then scaled using data from Webb (1970) on H_{Resp} for gas mixtures with different density x specific heat products to provide H_{Resp} values for air and the normoxic SF6 gas mixture. All calculations of H_{Resp} assume that 1) the inspired gas is dry, 2) the expired gas is fully saturated with water vapor, and 3) conductive heat losses are negligible. Results showed that H_{Resp} ranged from 12 to 40 W at rest, 44 to 80 W during light exercise, and 75 to 120 W during moderate exercise. When expressed as a percentage of total body heat production, H_{Resp} ranged from 8 to 23% at rest, 14 to 22% during light exercise, and 14 to 20% during moderate exercise. The H_{Resp} values reveal that increasing the convective character of the gas mixture results in only a minor benefit for reducing body heat load during shallow warm water diving. Furthermore, the data predict that switching from warm to cold gas breathing will reduce body heat load by an additional 10 to 15% during resting conditions, but that the benefit of cold gas breathing will diminish as work load increases. These findings likely reflect the fact that H_{Resp} for dives at or near surface pressure is predominantly dependent upon evaporative cooling (Hoke *et al.*, 1976). Experiments are currently planned to test these predictions.

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