

21 Prediction of severe body cooling in a hypobaric environment

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Major changes in the heat transfer processes on the human body under hypobaric environments occur in heat transfer coefficients for convection ($h'c$) and for evaporation of sweating ($h'e$). A ratio ($h'e/h'c$) is known as the Lewis relation and is defined in terms of barometric pressure (P_b), in Torr, by $LR=(h'e/h'c) = 2.2(760/P_b)$. In the equation above a term ($h'c$) is also affected by (P_b) and is given by $h'c=hc (P_b/760)^{0.55}$, where (hc) represents a sea level value. These relationships indicate that at 0.4 ATM the rate of convective heat loss decreases as much as 40%, contrary to the evaporative cooling power of the environment which increases up to 50%. The following equation describes the rate of respiratory dry and evaporative heat losses, ($C + E$) res, at a barometric pressure P_b in terms of the rate of pulmonary ventilation and enthalpy difference between exhaled and inhaled air.

$$(C + E) \text{ res} = V_{btps} \cdot (P_b - P_a) / 760 \cdot 10^3 / 28.34 / T \cdot (i_{ex} - i_{in})$$

where:

V_{btps} = pulmonary ventilation, body temperature and pressure, saturated with water vapor in l/hour

P_a = ambient vapor pressure in Torr

T = absolute temperature in K

i_{ex}, i_{in} = enthalpy of exhaled and inhaled air in kcal/kg.DA

As is well known the volume of pulmonary ventilation increases inverse-proportionally to the barometric pressure. And furthermore enthalpy of expired air increases significantly under hypobaric conditions, since the water vapor content is not affected by ambient pressure in the thin air. Thus assuming the exhaled air is saturated with the water vapor, the product of the increased V_{btps} and enthalpy difference ($i_{ex} - i_{in}$) is several times as much at high altitude compared with sea level conditions. For example at 0.4 ATM or at an altitude of about 7000 meters with ambient air temperature of minus 30 degrees C, man may lose 80 to 100 kcal of body heat in one hour, since his pulmonary ventilation rate is expected to increase as much as five times, and this heat loss corresponds to the resting metabolic energy. In other words man may lose all of his metabolic heat through respiration. It seems that quite a few numbers of fatal accidents at high altitudes might be caused by the failure of physiological adaptation related with the hypoxia. However, severe body cooling resulting from hyperventilation may also easily extend the climber to the limit of his physiological tolerance.

22 Effects of training at altitude on physical performance

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Study of mechanisms of high altitude physiology and acclimation to hypoxic stress particularly under the added stress of exercise has been a popular topic of investigation for more than a century. The term hypoxia is derived from Greek and means simply "less than a normal amount of oxygen". Hypoxia resulting from altitude exposure is termed hypoxic hypoxia and results in a reduced arterial oxygen content from a decrease of the partial pressure of oxygen in inspired air (P_{iO_2}).

Strenuous exercise itself induces an arterial hypoxemia in athletes under normobaric conditions and thus athletic performance is particularly compromised at altitude.

Devising methods to minimize the effect of an oxygen deficiency in the surroundings is a challenging environmental ergonomic problem and has been attempted by a variety of methods including:

- i) Hypobaric exposure of subjects in decompression chambers prior to hypoxic exposure
- ii) Chemical suppression of negative metabolic reactions to hypoxia
- iii) Prior attainment of a high degree of fitness by potential altitude sojourners