iv) Design of optimal patterns of movement to high altitude in order to minimize its debilitating effects through gradual acclimatization
v) Design of portable devices simulating altitude effects which may be worn while training in normobaria in order to effect prior acclimation

The effectiveness of these methods will be analysed in this review particularly in light of the varying cardiorespiratory characteristics required to operate at peak levels at medium or high altitudes revealed in the recent literature by such studies as Operation Everest I (American Everest Scientific Expedition) and Operation Everest II (the USA I.E.M. 40 day decompression chamber expedition).

23 **Cardiorespiratory adjustments to work in cold hypoxic environments**

A. La Prairie, I.B. Mekjavic, O. Eiken [1] and *E.W. Banister,* School of Kinesiology, Simon Fraser University, Burnaby, British Columbia, Canada,
[1] Department of Environmental Medicine, Karolinska Institute, Stockholm, Sweden

During submaximal workrates, a competition exists between the cutaneous circulation and the working muscles for blood, the former attempting to enhance heat loss and thus maintain thermal equilibrium, and the latter to adequately supply the muscles with oxygen. The present study investigates the adjustments made during exercise in hypoxic environments and also examines the added effect of cold on the cardiorespiratory and thermoregulatory systems.

Six male subjects exercised on a bicycle ergometer at 50% of their maximal working rate, at an ambient temperature of 0°C and 20°C, inspiring either 20% O_2/80% N_2 or 12% O_2/88% N_2. Subjects participated in the exercise trials on a weekly basis. The order of the trails was randomized and periodic tests of maximal oxygen consumption were conducted throughout the experimental period to account for any training effect.Physiological variables were monitored continuously during a five minute period of unloaded pedalling and the twenty minute work regime. The non-invasive Fick method was used to assess cardiac output and stroke volume during minute fifteen of the work period.

Results indicate no difference in the core temperature or cardiac output during the four experimental conditions: I. Normoxia/20°C; II. Normoxia/O°C; III. Hypoxia/O°C; and IV. Hypoxia/20°C. In the normoxic conditions (I. and II.) the reduction in heart rate during exercise in O°C was accompanied by an elevated stroke volume. Hypoxic environments (III. and IV.) induced dramatic increases in ventilation and heart rate with a concomitant decrease in stroke volume.

It is concluded that a cold environmental stimulus in hypoxic environments aids venous return by enhancing vasoconstriction. The cold ambient conditions allow a greater dissipation of metabolic heat generated through exercise and thus reduce the competition for blood between the exercising muscles and the cutaneous circulation.

Session V
Human Performance in Hyperbaric Environments
Abstracts 24-29

24 **Modelling human exposure to altered pressure environments**

T.R. Hennessy, Admiralty Research Establishment, Teddington, Middlesex, United Kingdom

During a reduction in environmental pressure inert gas forms in some tissues and if the pressure drop is too large or rapid a critical excess quantity of undissolved gas will develop in a particular tissue, resulting in decompression sickness. Hence it is necessary to predict the uptake and elimination of both dissolved and undissolved inert gas in these tissues throughout an exposure to altered environmental pressure.

There are severe difficulties in developing a suitable model because the current end-point in determining the outcome of a decompression trial still depends on the bends incidence and the aviator/diver - doctor interaction which is subjective and imprecise, even when recompression therapy appears to confirm a diagnosis. There is no reliable independent method of inferring the dissolved and undissolved content of a particular tissue or the safe maximum limits relative to the environmental pressure.

Any tissue can be divided into an aqueous and a lipid component, each with a distribution of vascularity such that both diffusion and blood perfusion contribute to the exchange of metabolic gases. The simplest linear model (A), consists of four compartments - two diffusion-limited aqueous and lipid compartments and another two which are perfusion-limited. All four compartments are interconnected and interacting such that the overall tissue response is a quadruple-exponential function.

It can be shown that this four-compartmental model requires at least 14 parameters to describe the overall response to a change in the environmental inert gas pressure. If this tissue contains undissolved gas as well, then it may reasonably be simplified to a two compartment model (B), requiring another 4 parameters.

Assuming that just one compound tissue is involved in the avoidance of an excess of undissolved gas then the results of an experimental series will provide an estimate of the dissolved gas content of only one of the four compartments in model A. The estimate will depend on any undissolved content in one of the compartments in model B. It is known that only two compartments can be determined from data arising in one compartment and thus the 14 + 4 parameters cannot be solved unless data can be extracted independently from another compartment or by using another gas such as helium or neon on a different experiment.

It can be concluded that until some other independent end-point becomes availalbe, it will not be possible to develop a physiologically-based model of decompression. There is no justification for choosing a multi-parameter or multi-tissue model until new experimental data demands it. It is proposed that a best-fit double compartmental model be used for dissolved gas and a single compartment for undissolved gas (4 + 2 parameters). These are the simplest models consistent with the available data. These reduced models do not establish the method of converting a nitrogen response to that of helium or visa-versa.

Because of these limitations an experimental series must be carefully designed to reveal the tolerance of the above models and parameters as well as accumulating statistics.

25 Free flow in a deep diving helmet reduces the dead space to acceptable levels

D.E. Warkander and G.O. Dahlback, Chalmers University of Technology, Division of Underwater Technology, Goteborg, Sweden

One of the most critical characteristics of a diving helmet is the external dead space, which is added to the diver's internal dead space. The possible effects of an increased dead space are increased ventilation, CO_2 retention and finally the risks of intoxication, dyspnea and respiratory muscle fatigue.

To measure the external dead space of a common deep diving helmet (Kirby Morgan Superlite 17) we used a method with a fast mass spectrometer and a respiratory impedance plethysmograph giving a breath by breath analysis. Six divers participated in the study. The divers performed standardised work on a bicycle ergometer just below the surface in an open wet pot. The external dead space at rest was 0.26L BTPS and 0.32L BTPS at moderate work. When a free flow of 9 L/min was supplied to the helmet the external dead space decreased to 0.06 L BTPS and 0.16 L BTPS respectively. When the free flow was further increased to 18 L/min the external dead space decreased to 0.04 L BTPS at rest and 0.08 L BTPS. Two divers decreased their