2 Heat loss from the head in the cold

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The purpose of this study was to measure heat loss from the head during exercise in the cold. Three males and three females exercised on two occasions for 90 minutes on a treadmill at 4km/h in a climatic chamber controlled at -15°C, wind speed 4 km/h. The subjects were clad in arctic clothing (approximately 2 clo), with the head either fully exposed or protected by three layers: a balaclava, the hood of a sweat shirt and the hood of the parka. Heat flow discs and thermistors were taped to 14 skin sites, three of which were at the head: one on the forehead and one on each cheek. Additionally, core temperature was measured using a rectal probe. All sensors were scanned continuously and averaged per minute. The difference in total body heat loss between conditions was entirely accounted for by the difference in heat loss from the head. No significant differences in heat flow and temperature for other parts of the body were found, except for the chest, which had a higher heat flow and lower temperature with the head unprotected. This is probably the result of less insulation because of removal of the balaclava. Total body heat loss stabilized within 30 minutes. The forehead was always warmer than both cheeks, as would be predicted from anatomical differences in skin blood flow between these regions. Mean head tissue insulation, calculated to be 0.045 $m^2{}^oC/W$, was independent of head protection. Although females showed higher head tissue insulation than males in both conditions, the number of subjects was too small to provide statistical significance. In this particular experiment, heat loss from the head expressed as a fraction of total body heat loss was 6% with the head protected, and 17% with the head unprotected.

A mathematical model based upon the constancy of head tissue insulation was developed and has a striking resemblance with previously reported data. The model is further extended to include the effect of a variety of independent variables like wind, temperature, exercise and head protection. Heat loss from the head, expressed as fraction of total body heat loss, is predicted to reach values anywhere between 5 and 95%.

3 Expression of effect of thermal environmental parameters upon the human body based on heat balance equation

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The purpose of this paper is to introduce indices, which indicate the effect of each environmental factor on the human skin temperature and thermal sensation, based on the humid operative temperature, i.e. heat balance equation between the human body and its surroundings. Two new kinds of environmental indices concerning the effects of air movement and humidity were introduced by the development of the heat balance equation in the same manner of the development of the effective radiation field from the operative temperature: an index for air movement was provisionally called "thermal velocity field TVF" and another one for humidity was "reduced-effective humid field RHF". The former represents an energy field related to the independent influence of air velocity except evaporation and the latter indicates an energy field of the effect of humidity. Then experiments for confirming the indices were carried out so that two indices could fairly express the effect of each parameter on mean skin temperatures and thermal sensation vote. As for an index on the total effect of thermal conditions the Corrected Humid Operative Temperature HOTV was developed. Its index is considered as the humid operative temperature corrected by air velocity and is formulated in the total sum of air temperature and effective temperature changes caused by thermal velocity field, effective radiant field and reduced-effective humid field. Although there was significant difference between two velocity levels less than 0.2 m/s and 0.8 m/s in relation between mean skin temperature and the humid operative temperature, there was no significant difference between them by the use of the corrected humid operative temperature instead of the humid operative temperature.