HUMAN SURFACE TO MASS RATIO AND HEAT STRESS - A CONCEPT REVISITED

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A commonly accepted view in both human and comparative physiology literature is that a high surface to mass ratio (A_D/M) is beneficial in the heat. This is based on the concept that body surface determines heat loss capacity for dry and evaporative heat loss (together with skin temperature and sweat rate) and that body mass determines the amount of heat producing tissues. In comparisons of males and females it was observed that the average male, being bigger (lower A_D/M) and fitter than his female counterpart, was at an advantage in heat stress due to his higher sweat capacity. However when sweat evaporation was limited, as e.g. in hot humid climates, the males could not utilize that advantage and females had lower strain due to their higher A_D/M ratio (Shapiro *et al.*, 1980). Recent work with thermal models (Havenith, 2001) was unable to reproduce such results and predicted that a large A_D/M, as in females, would be a disadvantage when working in the heat (all other factors being equal), irrespective of the climate type. Based on this, Shapiro *et al.*'s data were re-analyzed, and it was observed that due to differences in body mass the walking exercise used created a much lower metabolic heat production for the females, which may explain their results. It was decided to perform a similar experiment, but control this for metabolic heat production by using cycle ergometer exercise.

The effect of morphological factors (body surface area [A_D], body mass and A_D/M on heat stress responses in a hot wet (HW: 35°C 80% rh) and hot dry climate (HD: 45°C, 20% rh) of equal WBGT (± 31.6°C) were studied in 30 (16 males, 14 females) and 25 (16 males, 9 females) subjects respectively. Subjects exercised on a reclining cycle ergometer for 60 minutes after 30 minutes rest in the heat. The workload was set at 60 Watt. Subjects varied in morphology (HD: A_D/M=270±21 $cm^2.kg^{-1}$; A_D=1.85±0.21m^2; mass=69.3±12.6 kg, $\dot{V}_{O_{2max}}$ =3.09±0.66 $l.min^{-1}$; HW: A_D/M=269±22 $cm^2.kg^{-1}$; A_D=1.90±0.20m^2; mass=72.2±13.0 kg, $\dot{V}_{O_{2max}}$ =3.56±0.88 $l.min^{-1}$). A_D/M was not significantly different between males and females.

The imposed heat stress elicited a large range of body core temperatures (T_{re}: HD range 37.5-39.1°C; HW range 37.5-39.0°C). The relation of heat strain (T_{re}) to morphology was identical in both climates (positive correlation of T_{re} with A_D/M, negative with A_D and mass), giving the bigger subjects an advantage. As $\dot{V}_{O_{2max}}$ was not equal for all subjects, data were also analyzed by ANOVA (high versus low A_D, body mass and A_D/M groups respectively), with $\dot{V}_{O_{2max}}$ as covariant. Differences between high and low A_D/M remained significant, though those for A_D and body mass became less (HD: p=0.06 and 0.08; HW p>0.25). However, even after this correction, bigger subjects were at an advantage over smaller subjects in both climatic conditions. These findings contradict earlier studies but are consistent with model calculations.

Havenith, G. (2001) Individualized model of human thermoregulation for the simulation of heat stress response. *J. Appl. Physiol.*, 90: 1943-1954.

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