GROSS EFFICIENCY OF HUMAN LOCOMOTION IN A MODIFIED STEP-TEST IN WARM AND COLD ENVIRONMENTS

Juha Oksa, Hannu Rintamäki, Juhani Hassi & Sirkka Rissanen
Oulu Regional Institute of Occupational Health,
P.O. Box 451, Oulu 90101, Finland

INTRODUCTION

Relationship between energy consumption and external work is called efficiency and it is used to **describe** the economy of human locomotion. Environmental factors possibly modify this relationship **(1,2).** In this study the effects of warm (W, 20°C) and cold (C, -15°C) ambient temperatures on gross efficiency (Eff_g) in three different work levels were compared.

METHODS

Clothed (1.0 clo in W and **2.4** clo in C) subjects (n=6) performed a modified step test ascending to three different heights (20 min/height). Distance from the floor to the proximal end of os. humerus was measured. From this distance **20**, 35 and **50%** was used **as** step heights (SH) aiming to correspond light (SH1), moderate **(SH2)** and heavy (SH3) work, respectively (3). Oxygen consumption (VO_2), heart rate (HR), 15 skin temperatures, rectal temperature (T_r) and heat flux (3 sites) were measured. External work (W_e) and Eff_g was calculated.

RESULTS

In spite of about 3 kg heavier clothing in C, the mean W_e in both environments and in each stepping height differed only by 1 W, and consequently differences in Eff_g had to be due to variation in mean VO_2 **(0.2-0.5** l/min**).** The highest Eff_g **(14.8%)** was seen in C in heavy work but in W in the light work **(14.7%).** The lowest Eff_g was seen during light (11.2%) and heavy work **(12.4%)** in **C** and W, respectively (fig 1).

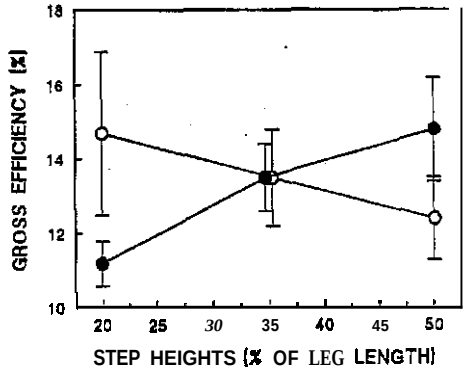

Fig 1. Eff_g (mean±SD) in cold (solid circle) and warm (open circle) temperatures in three different work levels.

Mean skin temperature and T_r did not differ between C and W experiments. However, leg skin temperature (mean of thigh and calf temperatures) and heat flux from the working calf muscles correlated rather well with the changes in Eff_g (table 1).

Table 1. Mean leg temperature (T_l, °C) and heat flux (HF, W/m²) from the calf, mean±SD, n=6.

		step 1	step 2	step 3
T_l	cold	30.3±1.8	31.3±2.4	32.511.2
	warm	32.2±0.9	33.2k1.1	33.4±1.0
HF	cold	143116	144±14	155±17
	warm	108±15	184225	198±14

CONCLUSIONS

There seems to be essential differences in Eff_g of human locomotion in various temperatures and workloads. The differences seem to be predominantly guided by local effects. Maximal Eff_g was achieved in leg skin temperatures (indicating the superficial temperature of working muscle) (4) of 32.2-32.5°C.

In light work the poorer Eff_g in C was probably due to the need to warm up the muscles.

In W, on the contrary, the activation of heat dissipation systems could be responsible for the lower Eff_g in moderate and especially in heavy work. In addition to leg temperatures, the increasing need for heat dissipation was also seen in heat flux from the calf, which in C was virtually unchanged but in warm increased as a function of decreasing Eff_g (table 1). In hot conditions respiration, circulation, sweating and the Q_{10} effect are activated (5), thus increasing total metabolism and diminishing Eff_g.

REFERENCES

1. Pendergast, D., The effect of body cooling on oxygen transport during exercise. Med. Sci. Sport., 5: 171-176, 1988.

2. Sawka, M., Pandolf, K., Avellini, B., Shapiro, Y., Does heat acclimation lower the rate of metabolism elicited by muscular exercise. Aviat. Space Environ. Med. 54: 27-31, 1986.

3. Lange Andersen, K., et al., Habitual physical activity and health. WHO Regional publications european series No 6, 1978.

4. Cooper, T., Randall, WC., Hertzman, AB., Vascular convection of heat from active muscle to overlying skin. J. Appl. Physiol., 14: 207-211, 1959.

5. Rowell, LB., Human cardiovascular adjustments to exercise and thermal stress. Physiol. Rev., 54: 75-159, 1974.