

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

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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).

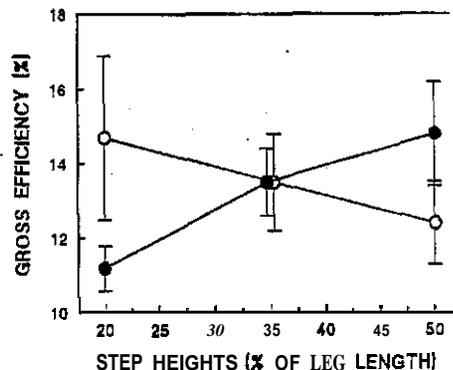


Fig 1. Eff_g (mean \pm SD) in cold (solid circle) and warm (open circle) temperatures in three different work levels.

Mean skin temperature and T_{re} 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	32.5±1.2
	warm	32.2±0.9	33.2±1.1	33.4±1.0
HF	cold	143±16	144±14	155±17
	warm	108±15	184±25	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 W 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 .

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