

# ACCLIMATION INDUCED BY EQUIVALENT STRAIN DUE TO EXOGENOUS AND ENDOGENOUS HEAT LOAD

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## INTRODUCTION

Heat acclimation is an important physiological counter-mechanism to avoid or reduce extreme thermal states of the body involving serious health problems including heat stroke. Adaptive adjustments may be evoked, e.g., within prophylactic health care programs in occupational medicine, either by (A) repetitive external heat load (e.g., in a climatic chamber) or (B) by repetitive endogenous heat load via muscular endurance training (e.g., on an ergometer).

This project aimed at a comparative quantification of the adaptational physiological responses to the processes induced by treatment (A) and (B). The extent and the time course of the responses, as well as the thermal and circulatory efficiency, were determined.

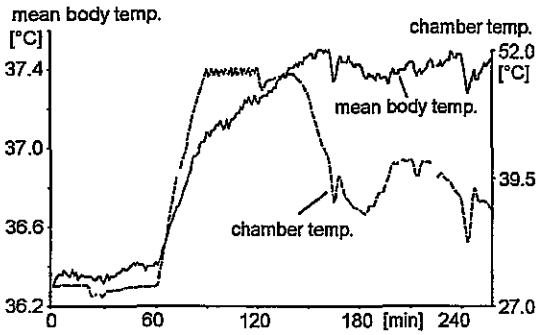
## METHODS

In contrast to former investigations (1,2,3) we guaranteed an equivalent thermoregulatory strain by experimental feedback of mean body temperature as physiological strain index, in case (A) to the temperature of the climatic chamber, and in case (B) to the mechanical power to be achieved on the ergometer.

By this, an increase of 1°C for mean body temperature ( $T_b = 0.87 T_{re} + 0.13 T_{st}$ ) was maintained during 2 h. Each type of experiment was repeated during 9 consecutive days. Before and after each series, a heat tolerance test was carried out: starting from a neutral environment, the temperature of the climatic chamber was increased every 30 min by 5°C, and a temperature of  $T_a = 45^\circ\text{C}$  (RH 20 %, wind speed 0.2 m/s) was kept for 45 min. After a second neutral phase, we determined the shivering threshold. Acclimation series (A), see Figure 1, started with a 60-min neutral phase and heating of the climatic chamber to  $T_a = 50^\circ\text{C}$ . As soon as  $T_b$  was 1°C above the initial level, a computer controlled  $T_b$  at this level by adjusting  $T_a$ .

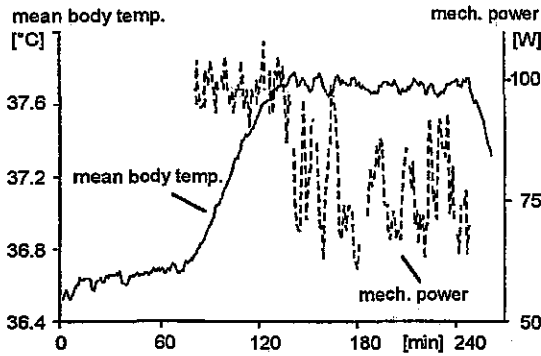
In series (B), see Figure 2, which was started not earlier than 4 weeks after the end of series (A) to guarantee sufficient de-acclimation, the subjects worked at  $T_a = 29$  to  $32^\circ\text{C}$  and performed 100 to 180 W mechanical power on a bicycle ergometer (after the initial resting phase) until  $T_b$  was 1°C above initial level.

The computer maintained this deviation by adjusting the workload. The intent in the second series was to reproduce the time course of  $T_b$  of the first series. One half of the 6 male subjects started with series (A), the other half with



**Figure 1.** Mean body temperature and chamber temperature in an experiment with exogenous load.

consumption and CO<sub>2</sub> production by respiratory gas analysis, heart rate, blood pressure, skin perfusion by Laser-Doppler-flowmeter and



**Figure 2.** Mean body temperature and mechanical power in an experiment with endogenous load.

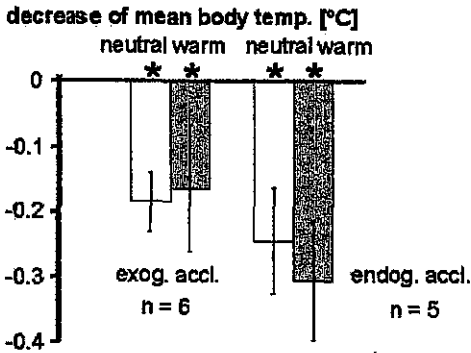
series (B). In any case, the temporal integral of the deviations of  $T_b$  from the value recorded at neutral initial conditions was equal in series (A) and (B). Measurements consisted of 10 skin temperatures, core temperature (rectal and radio pill), sweat production using 2 sweat collection capsules and by weighing the subjects, O<sub>2</sub> consumption and CO<sub>2</sub> production by respiratory gas analysis, heart rate, blood pressure, skin perfusion by Laser-Doppler-flowmeter and analysis of venous blood (before the heat tolerance tests: protein and electrolyte content and hematocrit) and sweat. The subjects did not take part in any sports or sauna, before or during the period of the experiments and attempted to avoid increased body temperature, heart rate and blood pressure, while at home during the period of the study.

## RESULTS

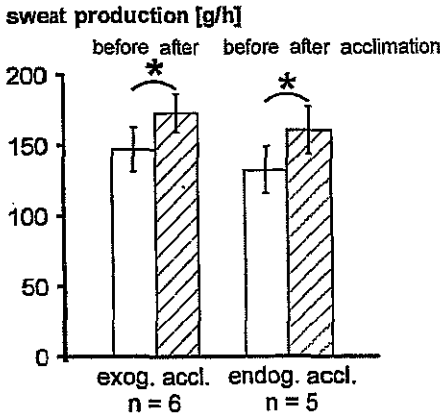
The prominent adaptive heat adjustments were a significant reduction of mean body temperature  $T_b$  revealed in the heat tolerance test before and after series (A) and (B), both for the neutral and the warm phase (Figure 3). The effect was primarily due to the decrease of core temperature, whereas we observed no clear effect on mean skin temperature. Differences between the two series were not evident, although a tendency of a stronger effect of the endogenous load occurred

Sweat production was significantly enhanced after both acclimation procedures (Figure 4); again significant differences between the procedures could not be detected.

The effect of increased sweating rate should be primarily due to the decrease of the sweating threshold, an effect that was statistically significant only in series (B).



**Figure 3.** Decrease of mean body temperature after exogenous and endogenous acclimation (white bars: neutral phase; shaded bars: heat phase of heat stress test)

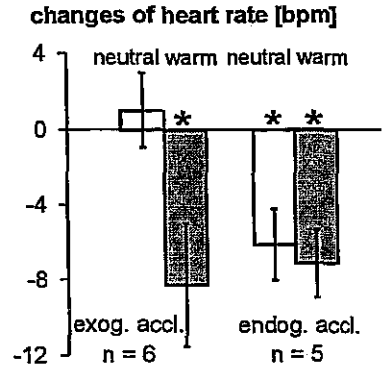


**Figure 4.** Sweat production after exogenous and endogenous acclimation (white bars: before; hatched bars: after acclimation).

## CONCLUSIONS

The results suggest that the temporal integral of the deviations of mean body temperature from the value recorded at neutral, initial conditions should be regarded as the essential indicator for the acclimation stimulus. With an equivalent value of this strain index, differences in the overall thermal adaptation grade could not be recorded. Successful and equivalent acclimation may be achieved by both external and internal heat production.

Also, heart rate was significantly reduced after both series in the heat stress phase (Figure 5), with a significantly greater effect by ergometer training. A uniform tendency of a decreased shivering threshold was obvious in both series. Also, the tendencies of increasing skin perfusion, blood electrolytes and decreasing hematocrit and sweat electrolytes after acclimation procedures were not significant.



**Figure 5.** Changes of heart rate after exogenous and endogenous acclimation (white bars: neutral phase; shaded bars: heat phase of heat stress test).

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