

## COLD-INDUCED VASODILATION IN THE HUMAN FOREARM

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### INTRODUCTION

Cold-induced vasodilation (CIVD) has been observed in the forearm during water immersion at 15°C and colder (1, 4, 5). Clarke et al. (1) observed that the CIVD is taking place largely in the muscle vessels of the forearm, but no rise of intramuscular temperature has been observed, possibly because it was hidden by the cooling of the tissue which was still important after 40 min of immersion in cold water. Whether a rise of intramuscular temperature during CIVD would be observed by prolonging the immersion time over 40 min has not been evaluated yet. The objective of the present study was to investigate the presence of intramuscular temperature increases in the human forearm during immersion in water at 15°C for 3 hours.

### MATERIAL AND METHODS

*Temperature measurements.* The tissue temperature ( $T_p$ ) of six healthy male subjects, aged 18 to 30 years was continuously monitored during the experiments, every 5 mm from the longitudinal axis of the forearm (determined by CT scan) to the skin surface. The temperature of the tissue was recorded with a fine calibrated multicouple probe (2) implanted on the bulkiest part of the forearm, approximately 9 cm distal from the olecranon process along the ulnar ridge. The forearm tissue temperature values were corrected for the thermal conductivity effect along the wires of the probe (2). Skin temperature ( $T_{sk}$ ) was measured, a few mm away from the site of the probe implantation, with a calibrated 40 gauge type T thermocouple.

*Hunting response of the tissue temperature.* The presence of CIVD response was determined under the criteria of a regular pattern of hunting reaction, as opposition to an erratic tissue temperature fluctuation. The intensity of the hunting reaction during the cold water immersion was determined for each depth inside the forearm by measuring the increase in tissue temperature during each cycle of the hunting reaction ( $\Delta T_t$  in °C), and a mean value of  $\Delta T_t$  was calculated for the complete immersion ( $\Delta \bar{T}_t$ ) at each specific depth inside the forearm.

*Heat flux measurements.* The heat flux from the skin ( $\dot{H}_{sk}$ ) of the forearm was continuously monitored during the experiments with two waterproofed heat flux transducers fixed on each side of the multicouple probe implantation. Each HFT was calibrated, and a correction was applied to the heat flux values for the effect of the thermal resistance of the HFT on the measured heat flux (3).

*Experimental procedure.* Subjects reported to the laboratory at noon of the experimental day. Following the muscle implantation of the multicouple probe, the subject, lightly dressed (T-shirt and casual pants), rested in a supine position under thermoneutral conditions (air temperature of 25°C, relative humidity of 40%) for 1 hour during which period,  $T_p$ ,  $T_{sk}$ , and  $\dot{H}_{sk}$  were recorded continuously. Then, the subject immersed his forearm and hand for three hours in a well-stirred water bath maintained at a constant temperature of 15°C.

### RESULTS

Five of the six subjects tested showed evidence of hunting reaction during immersion at 15°C. Figure 1 depicts the hunting reaction in the forearm muscle tissue during an immersion in water at 15°C for the subject showing the maximum response. For the 5 subjects showing evidence of hunting reaction, a significant increase of skin temperature was not observed for the complete duration of the immersion. Furthermore, muscle temperature did not increase during the first 55 minutes of immersion. However, after an immersion period of 55 to 90 min (mean value of  $75 \pm 6$  min), the muscle temperature began to increase, followed by a decrease. This pattern was repeated until the end of the immersion for an average of  $2.8 \pm 0.2$  cycles/subjects, the duration of the hunting cycles ranging between 30 and 45 min (mean value of  $36 \pm 3$  min). The  $\Delta \bar{T}_t$  values decreased with increasing  $r$  (distance between the longitudinal axis and each junction of the probe) to eventually achieve a value of 0 at the skin surface (Fig.1). The maximum  $\Delta \bar{T}_t$  values, observed in all cases at the longitudinal axis of the subject's forearm, ranged between 0.4 to 1.0°C (mean value of  $0.7 \pm 0.1$ °C). The heat loss from the forearm stabilized after ~60 min of immersion, and no concomitant increase of  $\dot{H}_{sk}$  was observed during the fluctuations of the muscle temperature.

### DISCUSSION

After an immersion period averaging 75 min, the muscle temperature of the forearm began to increase in 5 out of 6 subjects. Clarke et al. (1) showed no rise of muscle temperature of the forearm during 40 min of the cold water immersion at  $T_w < 18^\circ\text{C}$ , despite an early rise of the forearm blood flow during the cold

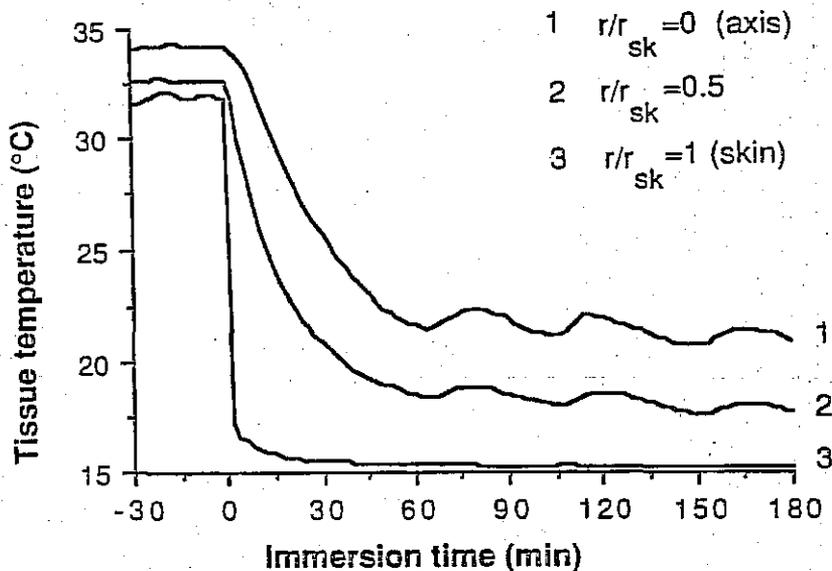


Fig. 1. Example of hunting reaction response observed in the forearm muscles during an immersion of the forearm in water at 15°C. The ratio  $r/r_{sk}$  is the relative depth inside the forearm, where  $r$  is the distance of the considered depth from the longitudinal axis of the forearm, and  $r_{sk}$  is the radius of the forearm.

stress. The absence of any rise of temperature in the forearm muscles may be due to the short period of immersion (40 min). The increase in forearm blood flow during CIVD, which would raise the temperature of the tissues as observed near thermal steady-state (75 min), merely reduces the rate and extent of cooling during the transient phase.

The observation that the tissue temperature fluctuation is limited to the muscle tissue is in agreement with the results of Clarke et al. (1), who suggested that the cold-induced vasodilatation takes place largely in the muscle vessels of the forearm. Since no increase in  $\dot{H}_{sk}$  was observed during the immersions, the reduction of the forearm muscle temperature following CIVD can not be attributed to an increased heat loss to the environment, but is probably due to the cooling action of the venous blood returning from the cold extremities on the temperature of the forearm tissues. It was also observed that the magnitude of the hunting reaction response ( $\Delta\bar{T}_t$ ) is dependent on the depth inside the forearm (Fig.1). The presence of the maximum hunting reaction response at the longitudinal axis of the forearm may be partly due to the concomitant CIVD of the hand and fingers, in addition to the cooling effect of the central venous return from the hand.

In conclusion, this study shows the presence of periodic increases of the forearm muscle temperature near thermal steady-state during water immersion at 15°C, the maximum increases being observed at the axis of the forearm.

#### REFERENCES

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