COLD-INDUCED VASODILATION IN THE HUMAN FOREARM

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INTRODUCTION

Cold-induced vasodilation (CIVD) has **been** observed in the foreann during water immersion at **15°C** and colder (1, **4**, 5). Clarke et al. (1) observed that the CIVD is raking 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_t) 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, approximatively 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 (ΔT_t in °C), **and** a mean value of ΔT_t was calculated for the complete immersion **($\overline{\Delta T_t}$)** 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 humitity of 40%) for **1** hour during which **period,** T_t, 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 ± 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 ± 0.2** cycles/subjects, the duration of the hunting cycles ranging between 30 and 45 min (mean value of 36 ± 3 min). The **$\overline{\Delta T_t}$** 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 $\overline{\Delta T_t}$ 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 ± 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°C,** despite an early rise of the forearm blood flow during the cold

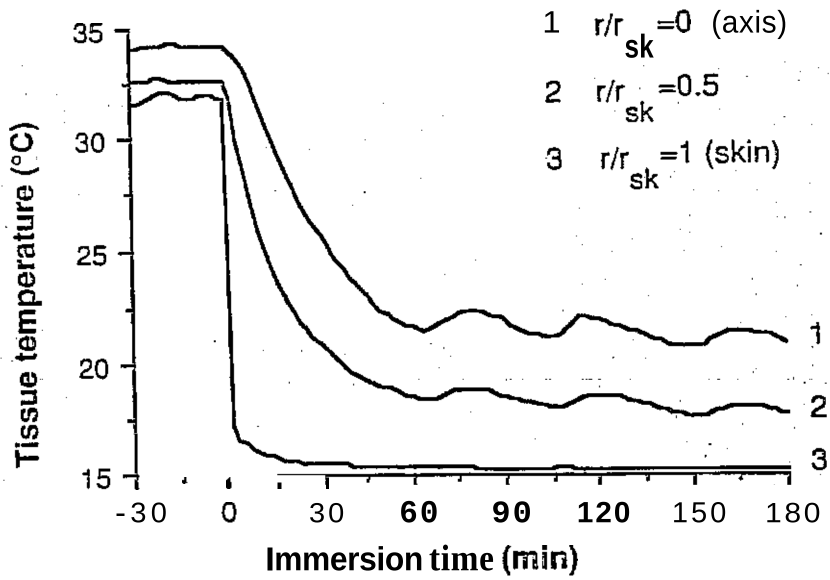

Fig. 1. Example of hunting reaction response observed in the forearm muscles during an immersion of the forearm in water ut 15°C. The ratio r/r_{sk} is the relative depth inside the forearm, where r is the distance of the considered depth from the longitudinal axis of the forearm, and r_{sk} is the radius 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** (**$\Delta \bar{T}$J** is dependent on the depth inside the forearm (Fig.1). The presence of **the** maximum hunting reaction response at **the** longitudinal **axis** of the foream 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 f o m muscle temperature near thermal steady-state during water immersion at 15°C, the maximum **increases** being **observed at** the *axis* of the forearm.

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