THE EFFECT OF WARMING UPON CORE TEMPERATURE RESPONSES TO A SUBSEQUENT COLD WATER IMMERSION

Carol M. Windle and Michael J. Tipton*
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Institute of Naval Medicine, Alverstoke, Hants, UK.
*Robens Institute, Surrey University, Guildford, UK.

INTRODUCTION

Estimations of survival time in cold water are important because they influence policies associated with survival including the protective clothing recommended for those at risk of accidental immersion and suggested search and rescue times. Previously, estimations have largely ignored the thermal state of the individual on immersion. Body temperature may increase as a result of activity, exposure to an external heat source, or from a combination of both these; helicopter pilots and passengers, fire-fighters and sportsmen could quite feasibly enter cold water with an elevated core temperature. These experiments were undertaken to determine the effect of warming by active and warming by passive means on the long term survival prospects of individuals subsequently immersed in cold water.

METHOD

Twenty-eight volunteers participated in the experiments. Each undertook two head-out cold water immersions (CWI) in stirred water, wearing swimming costumes. The temperature of the water was 15°C, and the duration of each immersion was 45 minutes.

Exueriment 1: Immediately prior to one CWI twelve subjects exercised on a cycle ergometer for approximately 20 minutes until their core temperature rose by 1°C or to 38°C (active warming). Prior to their other immersion the same subjects rested seated on the cycle ergometer for an equivalent length of time (control condition).
Exueriment 2: Sixteen different subjects were warmed in a hot bath at 40°C for approximately 20 minutes until their core temperature rose by 1°C or to 38°C (passive warming), they were then immediately immersed in the cold water. Prior to their other CWI they were immersed in the bath with the temperature of the water at 35.5°C (thermoneutral) for an equivalent length of time (control condition).

Rectal (T_{re}) and aural (T_{au}) temperatures were monitored continuously. Skin temperature (T_{sk}) was measured at the chest, abdomen, forearm and thigh and recorded every minute. Heart rate (f_C) was calculated from a three lead electrocardiogram (ECG) recorded continuously using a telemetry system. Oxygen consumption ($\dot{V}O_2$) was measured for three minute periods, upon CWI and then every fifteen minutes thereafter. The perceived thermal comfort of the subjects was also recorded.

The data from the two experiments were analysed independently. The rates of fall of T_{re} and T_{au} were calculated separately using simple linear regressions through the temperatures of each subject during the fmal fifteen minutes of CWI; analyses of variance were conducted to assess any differences between conditions.

RESULTS

Experiment 1. Warming by exercise (active): Upon CWI VO_2 did not differ between the two conditions. T_{sk} at all four sites fell rapidly when the subjects were immersed and stabilized within 2°C of water temperature during the first five to ten minutes of CWI.

f_C did not differ between the two conditions during CWI. VO_2 was greater from 15 minutes until the end of CWI when immersion was preceded by rest. The rate of fall of T_{re} during the last fifteen minutes of CWI when preceded by exercise was **2.46°C.hr^{-1}**, this was significantly faster ($P<0.01$) than the rate following rest **(1.68°C.hr^{-1})**; however at the time this faster rate was observed, the T_{re} in the exercise condition were still above those in the pre-immersion rest condition. The T_{au} profiles for the two CWI converged after 30 minutes and then fell at similar rates. Thermal comfort was lower during the final twenty minutes of CWI when immersion was preceded by exercise compared to rest.

Exueriment 2, Warming by immersion (passive): There was no difference upon CWI in $\dot{V}O_2$. T_{sk} at all four sites fell rapidly when the subjects were. immersed and stabilized within 2°C of water temperature during the first five to ten **minutes** of CWI,

f_C did not differ between the **two** conditions during CWI. $\dot{V}O_2$ was significantly greater at 15 minutes when CWI was preceded **by** warming ($P < 0.01$). Initially T_r and T_{au} fell at faster rates following warming than in the control condition and **as** a consequence the temperatures were the same **by** the 20^{th} minute of CWI, they then fell at similar rates. Thermal comfort was higher in the latter stages of CWI following warming.

DISCUSSION

On CWI most of the physiological alterations associated with the warming procedures will have, persisted, initially. These include **increased:** core temperature, **heart** rate and cardiac output. Following exercise, an increase in working muscle temperature and an exercise induced hyperaemia could result in up to ten-fold increase in skeletal muscle flow'. Following passive warming **skin** temperature and blood flow will have increased.

Subjects who **had** been warmed prior to CWI had a greater core-to-water temperature gradient **on** immersion. In addition, raised muscle blood flow following exercise will have increased tissue conductance and removed 70-90% of total body insulation that is thought to he provided **by** poorly perfused muscle in resting individuals immersed in cold water[2]. High cutaneous blood flow following passive warming resulted in a rapid fall in core temperature during the first minutes of immersion, faster than that **seen** with different subjects following exercise. In exercise the blood is redistributed to the muscle and therefore below the layer of subcutaneous fat, which may serve to reduce heat loss when compared with the high cutaneous blood flow **seen** following warming by immersion.

The faster fall in T_r during the fmal 15 minutes of CWI preceded **by** exercise may have been accentuated **by** the lower metabolic rates which occurred during these immersions. The finding that T_r fell more quickly during CWI following exercise **supports** that of McDonald et al **(1984)**[3], **on** the basis of their **finding** McDonald et al concluded that vigorous pre-immersion exercise may shorten survival time in cold water due to an increased **cooling** rate. In their study the faster rate of fall in core temperature during CWI occurred when temperatures were still above those following rest, and their conclusion was made without the knowledge of what would have happened to the core temperatures after they had converged. It is possible that the faster rate of fall of core temperature established following exercise might have continued; it is also possible however, that following convergence the fall in core temperature would have continued at the same rate to that established following rest, resulting in a similar survival time. The results of the T_{au} data in the active warming experiment support the second of these possibilities. The results from Experiment 2 also suggest that once the core temperatures during CWI following warming have fallen to those in the control condition they will continue to fall at similar rates.

CONCLUSION

It is concluded that warming **by** either active or passive means is not beneficial and probably not detrimental, to long term survival prospects during a subsequent immersion in cold water.

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