COLD WATER IMMERSION OF THE HANDS AND FEET FOR COOLING HYPERTHERMIC INDIVIDUALS

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INTRODUCTION

Research has resulted in the development of a variety of novel cooling devices for alleviating heat stress. Many cooling methods are only effective for a limited period of time and require further cumbersome equipment. There is a technique which is inexpensive, simple to use and has been found to be very effective in reducing core temperature after exercise, that is hand immersion in cool water[1,2]. Foot immersion in water at 10°C has also been investigated for cooling individuals who had sat for 2 hours in air at 35°C wearing chemical protective clothing; this resulted in the removal of 150W of heat over 20 minutes[3]. This present study compared the effectiveness of hand immersion, foot immersion, and both hand and foot immersion, in water at 10°C for reducing the core temperature of subjects who had exercised in a hot environment.

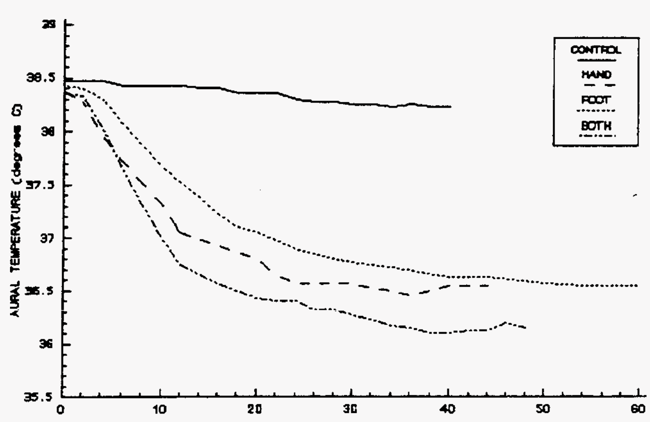
METHOD

Twelve subjects wearing two layers of thick and insulative fire protective overalls worked continuously at a rate of approximately 310W in a hot (40°C, 50%RH) environment, until their aural temperatures (monitored by thermistors inserted into each aural canal and insulated with cotton wool) reached 38.5°C. On reaching this temperature they sat and immersed: bare hands (hand immersion); bare feet (foot immersion); or bare hands and feet (both immersion) into insulated containers (one container for hands, two for feet) containing 15 litres (approximately 18 cm deep) of still water at 10°C covered by insulating foam; or undertook no limb immersion (control). Subjects were removed from the chamber for one of the following reasons: after 60 minutes; if there was no further fall in their aural temperature for 10 consecutive minutes (plateau); or if they withdrew at their own request. All conditions were completed in 4 consecutive days according to a Latin square design. Rates of change of aural temperature were analysed by repeated measures analysis of variance to compare conditions. The heat loss from the hands or feet to the water was calculated from the rise in water temperature measured by two thermistors positioned at a depth of approximately 9 cm.

RESULTS

All three cooling conditions (hand, foot, both immersion) produced a significant reduction in aural temperature within 10 minutes compared to the control ($P < 0.01$). Aural temperature remained above 38°C in the control condition. The average cooling rates (standard error) between 3 and 10 minutes were: 0.48 (0.09)$°C.h^{-1}$ for the control condition; 5.45 (0.33)$°C.h^{-1}$ for hand immersion; 4.61 (0.36)$°C.h^{-1}$ for foot immersion; and 7.49 (0.38)$°C.h^{-1}$ for both immersion. When both were immersed the rate of cooling was significantly higher ($P < 0.01$) than for hand or foot immersion. The difference between hand and foot immersion was not significant. Fig 1 shows the aural temperature during each cooling condition for one subject.

Fig 1: The aural temperature-time profile of one subject



With foot immersion aural temperature tended to plateau at higher levels compared to both immersion. Five subjects reached a plateau with foot immersion with aural temperature ranging from 37.1 to 37.6°C within 37 to 48 minutes. All subjects had aural temperatures below 37°C after hand cooling, with the final aural temperatures of the two subjects who reached a plateau at 36.9 and 37°C (after 55 and 35 minutes respectively). With both immersed four subjects reached a plateau with their final aural temperatures ranging from 36.05 to 37.05°C within 35 to 58 minutes. Table 1 shows the time for aural temperature to fall by 1°C in each condition.

Table 1 - Time (mins) for aural temperature to fall by 1°C

	Subject											
Cooling Site	1	2	3	4	5	6	7	8	9	10	11	12
Hand	21	14	15	15	11	9	21	15	11	9	-	12
Foot	26	x	23	10	8	14	15	x	25	13	x	19
Both	9	10	21	6	5	12	-	8	9	8	10	6

x = fall in core temp less than 1°C; - = absent from condition

The average heat transferred from the hands and feet to the water for each cooling condition is shown in Table 2. When both were immersed the heat transferred to the water from the hands was less than for hand immersion alone, and the heat transferred from the feet was less than with foot immersion alone. However the total heat transferred with both immersion was greater than for either hand or foot immersion.

Table 2 - Heat transfer (W) to water - first 10 mins of cooling (N=9 due to some missing data in 3 subjects)

	Hand or Foot			Both		
Cooling Site	Average	Min	Max	Average	Min	Max
Hands	272	168	377	183	26	284
Left Foot	172	68	254	115	28	195
Right Foot	180	100	254	122	73	195

CONCLUSIONS

The results indicate that immersing the hands and feet together in water at 10°C is an effective way of lowering the core temperature in individuals who have become hyperthermic through exercising in hot climates whilst wearing protective clothing. Hand immersion and foot immersion are equally effective if the cooling period is limited to 10 minutes. However hand only immersion is likely to be more beneficial if longer periods are available as the aural temperature tends to level off at a lower level when immersing the hands. The technique of hand and foot immersion would not be very effective and heat loss would be reduced if the cold stimulus caused local vasoconstriction. The skin temperature of the hands and feet must therefore be above the threshold for vasoconstriction. This threshold may be lowered with increasing core temperature'. The lower quantity of heat transferred to the water in the first 10 minutes of cooling from the hands and from the feet with separate immersion compared to the simultaneous immersion of both, suggests a greater local drive for vasoconstriction when a larger surface area is exposed to a cold stimulus. It is suggested that the slowing of the rate of cooling with time is a combination of the reduction in core temperature to water gradient and a reduction in the central drive for vasodilation as the core temperature falls. The difference in the level at which the aural temperature plateaued in the hands and feet could be explained by the anatomical differences between them. Another suggestion is that the feet have a lower central drive for vasodilation compared to the hands and/or a higher local drive for vasoconstriction.

REFERENCES

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