

in 10°C water on five separate occasions. During the first immersion, subjects wore only shorts, while in the remaining four immersion trials they wore the four suits under evaluation. In addition to the helicopter suit, subjects wore long cotton underwear, a long-sleeved cotton undershirt, woolen socks, boots and gloves. Suit D was a thin Nomex coverall, to be worn above a short long-sleeved neoprene wet suit.

The second part of the study evaluated the suit in simulated summer cockpit conditions. Subjects were seated in an Environmental Chamber at an ambient temperature of 20°C. The temperature of the chamber was elevated linearly to 40°C over a one hour period and the subjects remained seated in the chamber for a total exposure of three hours.

Results indicate that suits C and D (wet suit concept) offered better thermal insulation during cold water immersion. Subjects wearing suits A and B during head out immersion in 10°C water had a much greater cooling rate. During the hot air exposure, greatest elevations in core temperature during the three hour exposure were observed in subjects wearing suit C (Nomex/Insulite). Suit assembly D (Nomex coverall with a long-sleeved short wet suit) appeared to have the best overall performance results. It offered adequate protection during cold water immersion and did not induce excessive heat stress during the hot air exposure.

It is concluded that performance tests of constant wear thermal protective clothing should include tests of ventilation and permeability characteristics. Clothing fit is extremely important for adequate insulation, especially in suits based on the wet suit principle.

Acknowledgements

This work was supported by the Science Council of British Columbia and Mustang Industries Inc.

39 Does intermittent exercise during cold water immersion affect the metabolic response to cold stress and the surface heat flux?

P.J. Sowood, Royal Air Force Institute of Aviation Medicine, Farnborough, Hampshire, United Kingdom

Maintenance of body core temperature during cold water immersion depends upon the relative rate of heat production and surface heat loss. Additional body heat is obtained from shivering (and perhaps non-shivering) thermogenesis as well as a by-product of exercise.

This paper reports the results of an experiment designed to examine the relationship between shivering, exercise, surface heat flux, and change in core temperature during cold water immersions. Thirteen male subjects (aged 19 to 39 years) were immersed to the neck in thermoneutral water, and in water at 24°C and 18°C. Two immersions were conducted at each temperature; one whilst sitting at rest in well stirred water and another during which the subject pedalled an underwater cycle ergometer at set frequencies for 10 minutes followed by rest periods of 10 to 20 minutes. For each subject the pedalling frequencies used were identical in each of the 3 exercising immersions. Oxygen uptake ($\dot{V}O_2$ L·min⁻¹ STPD) was measured and total energy expenditure was calculated (Weir, 1949). Mean surface heat flux at 9 sites (Bell *et al.*, 1985), rectal temperature and ECG were monitored continuously.

For immersions conducted at 18°C, reduction in the metabolic response to the cold stress caused by the simultaneous exercise was significantly correlated with the exercise level ($R=0.80$; $p \leq 0.001$). Thus, a work rate that gave rise to an energy expenditure of 500W in thermoneutral water when performed in 18°C water produced a 50% decrease in the metabolic response to cold. In 24°C water, although the metabolic response was less, simultaneous exercise produced a reduction which was not well correlated with the exercise level ($R=0.45$; $p \leq 0.001$). In some subjects, even the lowest exercise rates completely abolished the increase in energy expenditure produced by immersion at 24°C. Of importance is the observation that mean surface

heat flux measured during resting and exercising immersions were not significantly different (paired t-test). The mean rate of fall of rectal temperature was significantly less during exercise at both cold temperatures:

mean rate of fall of rectal temperature °C/hr	18°C		24°C	
	Resting	Exercise	Resting	Exercise
	1.39	0.87	0.88	0.53
t-test p value	< 0.05		< 0.001	

Table 1.

These observations support the view that exercise only partially replaces the metabolic response to cold water immersion. At 24°C, although total energy expenditure is increased, the reduction in the metabolic response to the cold stress is variable and largely unrelated to the level of exercise performed. This difference may be explained by the difference in the amount of muscle involved in shivering at the two temperatures.

In these immersions exercise did not significantly increase the measured surface heat flux; an unexpected result supported by the observation that the mean rate of fall of rectal temperature was less in the exercising immersions compared to the resting condition.

All experiments conducted on human beings were performed with the informed consent of the volunteers in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

References

- Bell, P.Y., Padbury, E.H., Hayes, P.A. (1985) Optimal siting of heat flux transducers for the assessment of body heat loss when immersed in water. *Undersea Biomed. Res.* 12(4), 465-483.
- Weir, J.B.deV. (1949) New methods for calculating metabolic rate with special reference to protein metabolism. *J. Physiol.* 109, 1-9

40 Survival at sea: The effects of protective clothing and survivor location on core and skin temperature

A.M. Steinman, U.S. Coast Guard, Washington, DC, USA

A comparison of different types of protective clothing was made for maritime personnel exposed to three different survival environments: 1) immersion in cold, rough seas; 2) exposure to cold wind and spray atop an overturned boat in cold, rough seas; and 3) exposure to cold air and cold, rough seas in an open, one-man liferaft. The protective garments tested were: 1) uninsulated flight suit coverall (FS); 2) two-piece wet-suit (WS); 3) insulated, loose-fitting aviation coveralls (AC); 4) insulated, loose-fitting boatcrew coveralls (BC); 5) uninsulated dry-suit (NI); 6) uninsulated dry-suit with a 5 cm tear in the shoulder seam (NX). All garments were worn over cotton thermal underwear; an additional layer of insulated short-sleeve underwear was worn with NI and NX. An inflatable flotation device was worn with all garments except BC. The protective garments were tested in the survival environments as follows: Water immersion (FS, WS, AC, BC, NI, NX); Wind, spray and wave exposure atop the boat (FS, WS, AC, BC); within the liferaft (FS, WS, AC, NI, NX). Eight volunteer Coast Guard crewmen were used as test subjects; mean age = 23.5 ± 2.7 years; mean height = 175.0 ± 2.2cm; mean weight = 71.7 ± 3.7 kg; mean body fat = 11.1 ± 2.2%. Water temperature was 6.1 ± 1.2°C; air temperature (T_{wb}) was 7.7 ± 2.7°C; air T_{wb} was 7.2 ± 1.5°C; wind speed was 7.5-10 m·sec⁻¹. Sea-state consisted of 1.5 m swells and 1.5m breaking waves every 30-45 seconds of sufficient force to totally submerge subjects in the water and to often engulf subjects atop the capsized boat; waves swamped the liferafts only