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# ASSESSMENT OF IMMERSION SUIT PERFORMANCE: HUMAN COMPARED TO IMMERSION THERMAL MANIKIN TESTS

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## INTRODUCTION

Immersion thermal manikins have been widely used to assist in the evaluation of immersion suits and the determination of survival policies. The 200g leakage limit for uninsulated immersion "dry" suits included in many standards, specifications and guidelines is but one example of a pass criterion that has been primarily determined following tests with manikins (1, 2). The question remains: to what extent can the use of such techniques rather than manned tests prejudice the evaluation of an immersion suit, and how appropriate for humans are pass criteria, established and tested on manikins? In an attempt to address this question a series of experiments were undertaken in which the data obtained from humans were compared with those obtained from an immersion thermal manikin.

## METHOD

The manned tests were undertaken at the Institute of Naval Medicine, Gosport, Hants., **UK.** Following ethical committee approval, informed consent in accordance with the code of ethics of the World Medical Association was obtained from 12 healthy male volunteers who were not cold habituated. Each subject undertook six immersions into agitated (with compressed air) water at 10°C wearing the following standardised clothing assembly: swimming trunks; long legged and sleeved cotton underwear; woollen socks; knitted woollen ankle to neck insulating garment; whole body "dry" uninsulated immersion suit with bellows neck seal, cross chest waterproof zip, integral rubber gloves and socks; leather ankle boots; and Royal Navy General Service lifejacket which lifted the uncovered head clear of the water.

At least four days intervened between the successive immersions of a subject. The immersion conditions were: A Zero leakage, natural flotation angle. B Zero leakage. C 200ml leakage (200ml leak). D 500ml leakage (500ml leak). E 500ml leakage over limbs (500ml leak [L]). F 1000ml leakage (1000ml leak). In condition A the subjects were allowed to assume a natural flotation angle and were then loosely tethered in this position. In conditions B-F the flotation angle of the subjects was fixed at 42°, the angle used in the manikin testing. Where leakage was to be introduced, the required volume was taken from the pool using a measuring cylinder and distributed evenly over either the front and back of the torso or over the surface of the four limbs using a pressurised sprayer. The water was introduced evenly throughout the layers of underclothing.

The immersions were terminated if any of the following withdrawal criteria occurred: absolute or rate of fall of core temperature remaining constant for a period of 20 minutes; subject request; appearance of any undesirable ECG waveforms; core temperature below 35°C. Deep body temperatures (aural and rectal), oxygen consumption, skin temperature (9 sites), and heat flow (4 sites) were measured during each immersion. An analysis of variance technique was used to examine the data collected. Total Insulation (body + clothing [Itot]) and Clothing Insulation [Icloth] were both calculated as previously described (3).

The thermal manikin tests were carried out using a 13 segment instrumented immersion thermal manikin (The Cord Group Ltd., Nova Scotia, Canada). Experiments B to F, described above for the manned tests, were undertaken and all tests ran for 240 minutes. The power consumption and Icloth values were obtained for each segment of the manikin throughout the tests. Every effort was made to ensure that the manikin test corresponded to the human tests to as large an extent as possible.

## RESULTS

The Icloth obtained from the manikin and humans were in general agreement and were significantly smaller than Itot. In the human experiments, a 500ml leak to the limbs produced a slower ($P<0.05$) rate of fall in deep body temperature (Fig. 1) and higher levels of body insulation (Itot-Icloth) than those seen with a 500ml leak to the torso. The relationship between conditions shown in Fig. 1 remained no matter which time period of immersion, or which deep body temperature was examined. In descending order of magnitude, regional heat losses with torso leaks in humans were: back, abdomen, forearm and calf. The corresponding order for the manikin (power consumption) was: calf, back, forearm and abdomen.

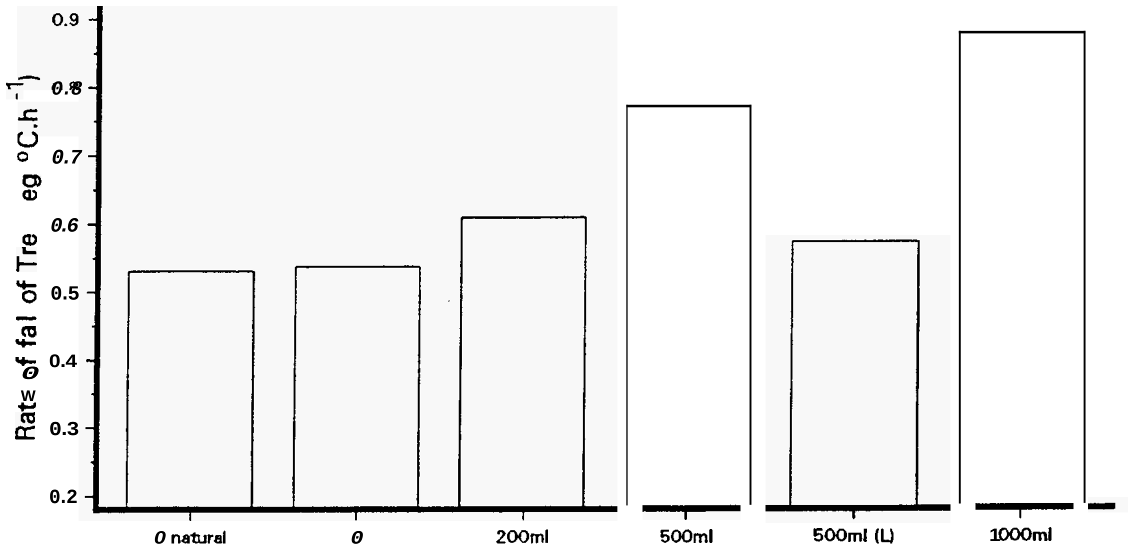


Fig. 1. The rate of fall of deep body temperature between the 40-70th minutes of immersion (n= **12)**

DISCUSSION

It is clear from the results that both the volume and position of any water ingress is critical to the level of protection provided by an immersion suit; a 500ml leak over the limbs resulted in deep body temperature responses which were equivalent to those seen with no leakage, whereas **a** 500ml leak over the torso produced responses in rectal temperature which fell, as expected between the responses seen with a 200ml and 1,000ml leak (Fig. 1). The results provided support for retention of the 200ml leakage limit for water leakage, as this volume of leakage did not produce falls in deep body temperature which differed significantly from those seen with no leakage.

It is primarily the physiological responses (peripheral vasoconstriction) to immersion in cold water that result in leakage to the limbs having a less detrimental effect on deep body temperature than an equivalent leak to the torso. Because they measure external insulation, the results from manikins provide no information on the effect which the position of **a** leak may have on deep body temperature. Indeed with the manikin, largely due to surface area effects, a 500ml leak over the limbs resulted in a greater reduction in insulation than an equivalent leak to the torso.

The potential for error arises when the external insulation figures obtained from manikins are used to make decisions pertaining to the clothing to be worn by humans or the code to be used in mathematical models predicting survival time. In the case of manikin tests any given insulation value can most easily be achieved by ensuring the suit provides at least the same amount of insulation, and preferably a little more, over the limbs compared to the torso. This is clearly the reverse of the ideal design for humans. This problem could be most easily rectified by having different insulation pass criteria for the limbs and torso. The average figure could remain at 0.3 clo but would be made up of a higher figure for the torso than the limbs.

It is concluded that manikin tests provide a good measure of external or clothing insulation but, when used to provide a single overall measure of insulation will not necessarily distinguish between suits which may provide quite different levels of protection for humans.

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