Surviving prolonged cold water immersion –
An evaluation of immersion dry suit test performance standards

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Introduction
Immersion dry suits are compulsory for offshore workers who are regularly at the risk of being exposed to cold water. The garments are worn in helicopter transit and are designed to be protective against the sudden skin cooling that triggers the ‘cold shock’ response (6), subsequent critical decreases in deep body temperature (hypothermia) and periodic wavesplash (sprayhood and lifejacket) which increase the risk of water aspiration and drowning (7). Dry suits significantly improve predicted survival times by minimising water ingress in contrast to wetsuits (5). The necessity for dry suit protection has culminated in standards for helicopter immersion dry suits (1, 2, 3). This study examined the performance of the Shark Group 1000 series dry suit in cold water. In so doing the test standards for suit performance in cold water were also assessed.

Methods
Six healthy, non-smoking participants (four male, two female) volunteered (mean [SD]; age 24 [4.0] yrs; height 1.74 [0.12] m; mass 68.94 [11.35] kg; BMI 22.5 [2.5]). Each participant was instrumented with a rectal thermistor, 14 skin thermistors and wore underwear, woolen socks, long trousers, a t-shirt, long-sleeved shirt, woolen pullover and the immersion suit. A volume of water (35mL), determined from a leakage test was added evenly to the liner of the suit. A lifejacket was put on and inflated prior entering 2°C water and resting supine for up to four hours. After three minutes of immersion the participants donned neoprene gloves; time taken to do this was measured. Withdrawal criteria were: deep body temperature <35.5°C; skin temperature of 4°C; skin temperature of 8°C >15 minutes (based on risk of non-freezing cold injury [NFCI]; 4).

Results
The gloves were donned after an average [SD] of 45 [13] s. None of the participants completed the four hour immersion; average exposure time was 139 [37] minutes. Three participants reached the limits of their tolerance and three achieved a skin temperature of 8°C for >15 minutes. The participants reported being very uncomfortable and very cold after two hours of immersion. The average rate of fall of deep body temperature was (0.33 [0.12] °C·hr⁻¹), providing a predicted average time to a deep body temperature of 34°C of >4 hours (estimated cLo: 1.33 [0.79]); >0.5 CLO (°C·m²·W⁻¹) was sufficient to pass).

Discussion
The helicopter immersion suit passed the test standard but the test procedure provides limitations and ethical concerns. The test is unnecessarily extreme; this explains why none of the participants completed the test. It is questionable from an ethical perspective to require humans to undertake a test that is more severe than is required. Immersed CLO can be achieved by immersion in water that is warmer than 2°C and that does not carry a risk of NFCI. Moreover, the buoyancy of the lifejacket and immersion suit assembly means the natural flotation angle adopted by participants results in a large percentage of the surface area of the suit being in air. Thus it is mixed ‘air and immersed’ insulation that is measured; the insulations determined from the test will appear high. Given that deep body temperature is required to be measured during the tests, some measured little point in estimating immersed insulation. Lastly, the relatively calm conditions of the tests do not accurately reflect the rough sea conditions which can significantly alter cooling rate (5). The test standard requires amendment to reflect real life scenarios without questioning from an ethical perspective to require humans to undertake a test that is more severe than is required. Immersed CLO can be achieved by immersion in water that is warmer than 2°C and that does not carry a risk of NFCI. Moreover, the buoyancy of the lifejacket and immersion suit assembly means the natural flotation angle adopted by participants results in a large percentage of the surface area of the suit being in air. Thus it is mixed ‘air and immersed’ insulation that is measured; the insulations determined from the test will appear high. Given that deep body temperature is required to be measured during the tests, some measured little point in estimating immersed insulation. Lastly, the relatively calm conditions of the tests do not accurately reflect the rough sea conditions which can significantly alter cooling rate (5). The test standard requires amendment to reflect real life scenarios without exposing volunteers to unnecessarily extreme conditions if suit performance, from the perspective of minimising cold-shock, time to reach hypothermia and ultimately reducing the risk of drowning are to be accurately assessed.

References

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