The thermal demands of flood rescue and impacts on task performance

Surf Life Saving GB recently collaborated with Portsmouth University to look at: The Thermal Demands of Flood Rescue and Impacts on Task Performance – a brief synopsis. The study was led by Prof M Tipton, Dr G Milligan, Mr A Mayhew and Mr C Abelairas-Gomez, with further support form Dr P Morgan.

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Flood rescue is an increasing part of flood response around the world, with many statutory services and volunteer services providing a flood rescue service.

Surf Life Saving GB (SLSGB) is a search and rescue charity whose volunteers have been providing beach lifeguard training and patrolling the coast for more than 70 years. The charity comprises some 9600 members who help to make our beaches safer and more enjoyable places for everyone. It was therefore a natural progression for SLSGB to look at flood rescue.

Considering flood rescue PPE

As a starting point, the charity considered the personal protection equipment (PPE) of 'flood rescue' kit.

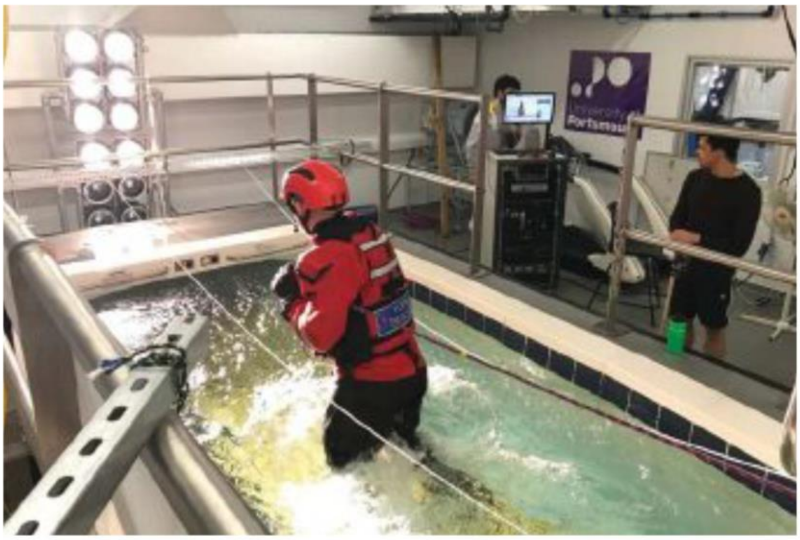
Prioritising keeping warm, managing the risk of contamination and protection against what is becoming widely known as cold water shock (*et al Prof Tipton and F Golden*) were just some of the assumptions made. There was no existing research on what happens to the flood responder (FR) while involved in basic tasks and what type of thermal profile FRs would have to manage while wearing full flood PPE. Also, little is known about cooling and heating in PPE during partial immersion (ie to the knee) in flowing water, as occurs in flood rescue.

Often forgotten, flood rescue can occur in warm climates, as was seen in the July 2007 floods in Worcestershire and Gloucester. With flood rescue history based on dealing with management of hypothermia, with future potential impact on global extreme weather, FRs need to understand how to manage the likelihood of hyperthermia.

Among other reasons, as flood water is contaminated, FRs are required to wear full flood rescue PPE. This

increases the hyperthermia signs and symptoms, which range from light headedness to heat stroke and could include the FR becoming unconscious (*Tipton 2015*). In simple terms, any moderate work will produce heat from the body and, because the PPE prevents full management of heat build-up, a fatal level of heat storage can be reached within 20 minutes (*Noakes et al 1991*).

> **"It is not acceptable to expect individuals to routinely work at their maximum capacity and to do so will result in fatigue and increase the likelihood of accidents."**



The test

The study involved 10 participants, who undertook two 'cold' condition scenarios, which required them to stand immersed to the knee in moving water (7.7°C), with simulated rain, for 60 seconds. Air temperature was 4°C and wind was set at 16km/h respectively.

For the warm day conditions, participants were required to walk (wade) in sessions of seven minutes in water at 15.6°C, pulling a controlling release of 10kg (the weight represented a raft with kit). The speed of water was originally set at 4.8km/h; this had to change as the first candidate to take the trial overheated within 10 minutes – the candidate was exhausted and had a heart rate maximum at 191 beats per minute (BPM), so the test was stopped. One interesting point to note, using the data from the first candidate's trial, it could be predicted that in 45 minutes the candidate's deep core temperature could potentially reach 40°C!

The water flow rate was then changed to 3.2km/h. The air temperature was 22°C with solar impact at 500W/m respectively. Participants were asked to r epeat this six times, with a three-minute rest between activities. Grip strength, manual dexterity, jump height and resuscitation (CPR) were measured pre and post exposures. These tests would represent potential areas, such as water rope rescue use, victim carries, self-rescue abilities (such as jumping into boats) and abilities to work on a submersed victim.

In the cold tests, cooling resulted in Great Toe (big toe) and finger temperatures of 9.98°C (0.84) and 10.38°C (14.00) respectively. Oxygen consumption rose from 7.46 (1.88) to 10.04 (3.13) mL/kg/min, jump height fell by 20%, manual dexterity deteriorated by 22% and grip strength fell by 13%.

In the warm tests, average heart rates were 157BPM, but maximum heart rates were all over 70% of VO2 max (based on theoretical 220-age). Oxygen consumption averaged 30.62 (7.83) mL/kg/min, and average sweat loss was 1.06-litres.

For the first time this study had looked at how the thermal demands of FRs in both cold and warm climates create impact on the body as defined by SME. It was hypothesised that remaining static in cold conditions would result in peripheral neuromuscular cooling, while exercising in warm conditions would result in significant increase in deep body temperature.

Findings Cold

The results demonstrated significant physical impairment following both scenarios. In the cold scenario the primary problem was the peripheral neuromuscular impairment, resulting in physical incapacitation, on tests requiring muscle function of a range of 13-22%, in just one hour. This reduction is due to the direct cooling on neuromuscular function (*Castellani & Tipton, 2015*). Maximal dynamic strength, power output, jumping etc are reduced by 4-6% per degree Celsius reduction in muscle temperature, down to 30°C (*Bergh & Ekblom, 1979*). At nerve temperatures below 20°C, nerve conduction is slowed and action potential amplitude is decreased (*Douglas & Malcom, 1955*). Nerve block may occur after exposure to local temperature between 5-15°C for 1-15 minutes (*Clarke et al, 1958; Basbaum, 1973*).

Implications for FR are in cold conditions. FRs may find it increasingly difficult to perform fine motor skills and tasks where leg power is required; rope work, wading, and jumping in and out of boats, first aid care, boat engine management etc. These decrements in performance should be taken into consideration when determining the physical requirements needed by FRs.

On health issues, it is worth noting that the peripheral skin temperature recorded during cold conditions (circa 10°C) and the circumstances of those conditions (dependant on limb, compressed tissues dues to foot wear and immersion) are very close to those associated with acquisition of non-freezing cold injury (NFCI), particularly when exposure times are extended (*Francis & Golden, 1985*). The pathogenesis and pathology of NFCI are poorly understood, but the life-long consequences of this injury are well-recognised; cold sensitivity, persistent intractable pain and hyperhidrosis (*Golden et al, 2013*). NFCI is a major cause of disability compensation claims with the military (*Lawyer Monthly, 2017*).

Findings Warm

Despite being immersed mid-thigh in flooding cool water, the combination of exercise-related heat production and warm ambient conditions of the warm trial resulted in an uncompensable increase in body temperature. This increase, plus the high heart rates, oxygen consumption and ratings of perceived exertion all suggested that in this condition people were working at their near maximum capability. Having introduced the work–rest schedules to the protocol, the subsequent oxygen consumptions and heart rates values reported in the warm flood rescue scenarios still represent 'extremely heavy work' (*Astrand et al, 2003*).

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It is important to consider what percentage of an individual's maximum capacity performing a task such as flood rescue should represent. When determining this percentage, consideration should be given to the duration of the task and its importance. For example, it is permissible to allow employees to work at a maximum capacity for a short duration followed by rest (*Goldman, 1999*). From these results it can be shown and demonstrated that it is not acceptable to expect individuals to routinely work at their maximum capacity and to do so will result in fatigue and increase the likelihood of accidents (*Parijat & Lockart, 2008*).

Within the warm tasks the increased VO2 demand demonstrated further demand on the body, and it is suggested (Louhevaara et al, 1986 Golden, 1999) that working at over 60% of the individual's VO2 max puts them at great risk of exhaustion. This means flood responders would require a VO2 max of approximately 51mL/kg/min. The percentage of sustainable VO2 max for intermittent work has not been documented; therefore, thought needs to be given to specific work–rest scheduling for flood rescue activities in heat, and consequent aerobic fitness.

Heat exhaustion and heat stroke

In warm conditions the physical demand of work is compounded by additional cardiovascular demand of high body temperature, this combination can lead to a switch to anaerobic metabolism and early heat exhaustion (*Ely et al, 2010; Cheuvront et al, 2010*). For managers of flood teams, this means keeping a close eye on individuals and looking out for the signs of dehydration, heat exhaustion and heat stroke; a critical medical condition, at a deep body temperature of >40.5°C (*Tipton, 2015*). This was seen in early stages with our first candidate. Venting, hydration and management of flood responders is essential, along with understanding the undergarments required for thermal regulation.

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