



Habituation of the cold shock response is inhibited by repeated anxiety: Implications for safety behaviour on accidental cold water immersions



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HIGHLIGHTS

- Accidental cold water immersion evokes the life-threatening cold shock response
- Repeated cold water immersion can induce a beneficial habituation (reduction) in the magnitude of the response
- This habituation may be disrupted by the coincidental experience of high levels of anxiety; we tested this hypothesis
- High levels of anxiety prevented or delayed habituation occurring
- Highly anxious individuals may not be protected by habituation if they experience high levels of anxiety on immersion
- Safety and survival training should consider measures to lower situation specific anxiety on immersion

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ABSTRACT

Introduction: Accidental cold-water immersion (CWI) triggers the life-threatening cold shock response (CSR) which is a precursor to sudden death on immersion. One practical means of reducing the CSR is to induce an habituation by undergoing repeated short CWIs. Habituation of the CSR is known to be partially reversed by the concomitant experience of acute anxiety, raising the possibility that repeated anxiety could prevent CSR habituation; we tested this hypothesis.

Method: Sixteen participants (12 male, 4 female) completed seven, seven-minute immersions in to cold water (15 °C). Immersion one acted as a control (CON1). During immersions two to five, which would ordinarily induce an habituation, anxiety levels were repeatedly increased (CWI-ANX_{rep}) by deception and a demanding mathematical task. Immersions six and seven were counter-balanced with another high anxiety condition (CWI-ANX_{rep}) or a further control (CON2). Anxiety (20 cm visual analogue scale) and cardiorespiratory responses (cardiac frequency [*f*_c], respiratory frequency [*f*_R], tidal volume [*V*_T], minute ventilation [*V*_E]) were measured. Comparisons were made between experimental immersions (CON1, final CWI-ANX_{rep}, CON2), across habituation immersions and with data from a previous study.

Results: Anxiety levels were sustained at a similar level throughout the experimental and habituation immersions (mean [SD] CON1: 7.0 [4.0] cm; CON2: 5.8 [5.2] cm cf CWI-ANX_{rep}: 7.3 [5.5] cm; *p* > 0.05). This culminated in failure of the CSR to habituate even when anxiety levels were not manipulated (i.e. CON2). These data were different (*p* < 0.05) to previous studies where anxiety levels were allowed to fall across habituation immersions and the CSR consequently habituated.

Discussion: Repeated anxiety prevented CSR habituation. A protective strategy that includes inducing habituation for those at risk should include techniques to lower anxiety associated with the immersion event or habituation may not be beneficial in the emergency scenario.

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1. Introduction

A conservative estimate suggests at least 372,000 people drown worldwide each year by accidentally entering water and failing to defend their airway against water ingress [1]. If the water is cold, the physiological responses evoked during the first few minutes of whole body

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cold water immersion (CWI) are life threatening [2] and are strongly implicated in this drowning statistic [3]. The initial responses to CWI include an “inspiratory gasp”, hyperventilation, tachycardia, peripheral vasoconstriction and hypertension, and are collectively known as the ‘Cold Shock’ response (CSR; [3]). The hyperventilatory component of the CSR significantly decreases maximum breath hold time in the majority of participants, thus increasing the chances of involuntarily aspirating water and drowning [4]; this represents a further hazard to that posed by the high cardiovascular strain [5]. The current behavioural recommendation to survive acute accidental CWI is to “float first and kick for your life” on the basis that the added buoyancy can enable greater freeboard (distance from water level to mouth of the victim) and the onset of leg-only exercise leads to a more rapid restoration of cerebral blood flow after its hyperventilation induced reduction on cold water entry [6]. The CSR subsides after the initial peak in the first 2–3 min following which swimming to safe refuge may become possible [7,8], with leg kicking being preferable to achieve this propulsion and to minimise heat loss [9].

For those at daily risk of accidental immersion (e.g. those undertaking leisure activities close to water, fishermen, aircrew or marine personnel) it is wise to take practical and safety precautions. One such precaution is to wear protective clothing to prevent rapid skin cooling on water entry, yet this is not always practical or logistically feasible [10,11]. An alternative is to reduce the extent of the CSR by inducing an habituation of the response; habituation is defined as reduced response to a stimulus of the same magnitude [12]. This can be achieved by undergoing a series of cold-water immersions which has shown to induce an habituation after as few as four short (three- or five-minute) exposures on consecutive days [13,14]. Indeed an habituation of the CSR reduces the respiratory portion of the CSR by approximately 44% and the extent of tachycardia by approximately 22% [15]. The benefit of this reduction is retained fully for seven months after consecutive exposures and is partially retained for up to 14 months [15]. Hence, retaining an habituation is not a labour intensive process and is practically feasible. Theoretically, reducing the CSR may confer some benefit to defending the airway in the emergency scenario as the hyperventilatory drive seen in unhabituated participants is significantly reduced [13].

The variation between individuals in the CSR on initial immersion and its habituation is large, and recent evidence suggests it may be strongly influenced by psychological state both prior to, and during a CWI [14,16–18]. Indeed, it has been shown that there are salient moderating influences on the extent of the CSR which are, at least in part, caused by high by contrast to low levels of anxiety [17]. The available evidence suggests that acute anxiety can significantly increase the magnitude of the CSR in unhabituated participants and partially reverse the habituation in those who have completed repeated CWIs [17]. Conversely, anxiety associated with the immersion scenario per se can be reduced by repeatedly experiencing the immersion sequence (i.e. repeated thermoneutral water immersion; 35 °C) in the absence of a repeated cold-water stimulus. One consequence of this lowered anxiety was a partially reduced ventilatory (i.e. tidal volume; V_T) response to CWI [18]. Accordingly, we concluded that repeated immersion in thermoneutral water induces a perceptual habituation of the threat posed by imminent immersion and this confers some benefit even when the water temperature is cold.

Collectively these data raise the possibility that it is the degree of the anxiety experienced prior to and during an immersion that determines if habituation occurs, with low levels of anxiety enabling habituation and high, continuous levels preventing it. The latter suggestion has yet to be examined experimentally probably because of the difficulty in sustaining high levels of anxiety throughout a series of experimental immersions. It is possible that the concomitant experience of anxiety disinhibits the transmission of thermal afferent information such that it magnifies the CSR response or prevents habituation [19]. Accordingly the present study examined the possibility that the repeated experience

of anxiety during a series of cold-water habituation immersions prevents significant habituation of the CSR. These data will be compared to those from our previous study where habituation was achieved and subsequently reversed by the induction of acute anxiety on immersion after cold-water habituation had taken place [17].

We hypothesised that low levels of acute anxiety are permissive of CSR habituation, but heightened anxiety, maintained throughout the duration of the immersion and the series of habituating immersions, would prevent habituation occurring (H_1). Similar to our previous studies, deception about the water temperature was used to elevate anxiety. In addition to this an anxiety-inducing maths task, with the punitive consequences of poor performance leading to an extended immersion duration, was also undertaken to elongate the anxiety that was induced.

2. Materials and methods

The Research Ethics Committee of Portsmouth University granted ethical approval for the study which was performed in accordance with the ethical standards of the 1964 Declaration of Helsinki. The participants gave their written informed consent to participate in cold-water immersion experiments lasting up to 7 min.

2.1. Experimental design

The present study utilised a within participant repeated measures design with between groups comparisons also made to data from a previous study [17]. Two groups were tested:

Group 1 – Repeated Anxiety & CWI (CWI-ANX_{rep}): Participants undertook seven, seven-minute CWIs (water temperature; T_w 15 °C). Immersion one was used to establish the extent of the CSR and acted as a control (CON1). During immersions two to five the participants' anxiety levels were raised using deception and a demanding maths task (see below). Immersions six and seven were counter-balanced to include one further anxiety inducing immersion (CWI-ANX_{rep}) and one further control where no anxiety inducing manipulations were undertaken (CON2).

Group 2 – Acute Anxiety & CWI (CWI-ANX_{ac}). Participants undertook seven, seven-minute CWIs (15 °C). Immersion one was used to establish the extent of the CSR and acted as a control (CON1). Immersions two to five were conducted without intentionally increasing anxiety. Immersions six and seven were counter-balanced to include one acute anxiety inducing immersion (CWI-ANX_{ac}) by way of deception about the water temperature only and one control where no anxiety inducing manipulations were undertaken (CON2); these data were drawn from our previous work ([17]; study 2). All experimental immersions (i.e. in both groups) were standardised; they took place at the same time of day (within-participant), with a minimum of 24 h and a maximum of 48 h between immersions, were to the same depth and each lasted 7-min. Fig. 1 shows the order of the experimental conditions in each group.

2.2. Participants

2.2.1. Common characteristics

The participants were non-smokers and were not cold water habituated. They abstained from alcohol and caffeine consumption for 24 h before each test and from undertaking any exercise on the day of the test.

2.2.2. Group specific characteristics

Group 1 – CWI-ANX_{rep}. Sixteen healthy participants (12 male, 4 female) volunteered for the experiment. Their physical characteristics were (mean [SD]): Age 21 [2] yrs; height 1.76 [0.1] m; mass 78.0 [18.0] kg; sum of skinfold 42 [18] mm).

Group 2 – CWI-ANX_{ac}. Ten healthy participants (6 male, 4 female) volunteered for the experiment. Their physical characteristics were

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