ECG and heart rate during helicopter underwater escape training (HUET) of novice trainees

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INTRODUCTION

In many countries it is a requirement for those working in the military or offshore oil industry to undertake Helicopter Underwater Escape Training (HUET). The staged, incremental training culminates in simulated ditching in which the trainees escape from a submerged, inverted mock up of a helicopter. Usually the water is warm and the duration of breath holding required to make an escape is short (<15s).The ditching is undertaken several times to improve confidence and consolidate the training. Repeated cold immersions have been shown to reduce the heart response and discomfort (Golden & Tipton, 1988).

Cardiac arrhythmias have been reported in shallow and deep breath hold dives (Schoander et al, 1962; Ferrigno et al, 1991). Possible mechanisms include hypoxaemia and respiratory acidosis during prolonged breath holding as well as atria stretch and vagal stimulation. HUET can produce anxiety in trainees (Robinson et al, 2008); such stress usually: results in the release of the stress hormones including adrenaline; increases heart rate and raises blood pressure (Bishop and Reichert, 1970). These responses are characteristic of the “alert (fight or flight)” response, mediated by the sympathetic nervous system (SNS). The cardiac response to such stress may be modified if the parasympathetic nervous system (PNS) is coincidentally stimulated. This can occur when an individual is submerged in cold water when apprehension plus cooling of the skin stimulates the SNS, in the latter case via the “cold shock” response (Tipton, 1989). Sudden cooling of the face (ophthalmic division of the trigeminal nerve) stimulates the PNS producing a bradycardia via the “diving response” (Bert, 1870).

Such coincidental stimulation of the PNS (face immersion and breath holding) and SNS with (anxiety and cooling) can cause “*autonomic conflict*” (Tipton et al, 2009) characterized by fluctuating and disturbed chronotropic inputs to the heart (Tipton et al, 1994). We have suggested that autonomic conflict is the cause of the high incidence of cardiac abnormalities during, and particularly just following, breath holding in water (Tipton et al, 1994; Datta & Tipton, 2006). These arrhythmias are usually supraventricular and asymptomatic, they also appear to be idiosyncratic for an individual (Tipton et al, 1994).

Therefore, in theory, autonomic conflict could occur during HUET; the present study tested this possibility. Given the large number of people undergoing HUET each year, and the absence of any reported cardiac problems, it was hypothesized that either ECG irregularities do not occur or, if they do, they are asymptomatic. It was further hypothesized that the heart rate response to HUET would habituate.

METHODS

Following ethical approval and informed consent, 26 naïve males completed five training runs in the HUET into water at 29.5°C. Each HUET run was separated by at least 10 minutes (similar to a training scenario) and standardized: the participant entered the HUET helicopter and was secured into the seat with a four point harness. This plus the ditching briefing took 90s. At 3.5 minutes the dunker was submerged and rolled to the inverted position, this took 10s. Once inverted the participant escaped, this took an average of 10s during which they breath held. The participant then floated supine until 4.5 minutes had elapsed. On a separate occasion the "resting" heart rate of each participant was established whilst they lay quietly in a darkened room for 15 minutes.

Participants wore a three lead (V5) telemetric ECG system (Sharktooth, MIE). They wore underclothing and an immersion dry suit. Skin temperature was measured in one subject on the chest, forearm, scapula and forehead. The ECG trace was examined independently by a clinician and appropriately experienced thermal physiologist.

Participants refrained from eating, smoking and drinking alcoholic or caffeinated drinks for 12 hours prior to attending the laboratory. They also undertook no vigorous exercise for 24 hours before testing.

Data were assessed for normality of distribution and a repeated measures Analysis of Variance was undertaken with post-hoc pair-wise comparisons. Alpha was set at 0.05.

RESULTS

Participants had raised heart rates prior to being submerged, indicating sympathetic activation. Heart rate increased during the HUET (Figure 1) more probably due to anxiety and physical effort than cold shock as measured skin temperature did not fall.

Average resting heart rate in air was 68.6 $bt.min^{-1}$ (n=26). During the HUET, heart rate was significantly lower pre-submersion at Min 1 and 2 in Run 1 compared to all other Runs (Figure 2) at these times. This position was reversed for Min3-3:30, when a significant habituation was seen in HR (*i.e.* anxiety-related heart rate in air); no difference was seen between any of the other Runs pre-submersion at these times. During submersion heart rate was lower in Run 5 compared to Run 2. Following submersion (*i.e.* on the surface 3:50-4:30min), heart rate fell over the first four Runs but did not change between Run 4 & 5.

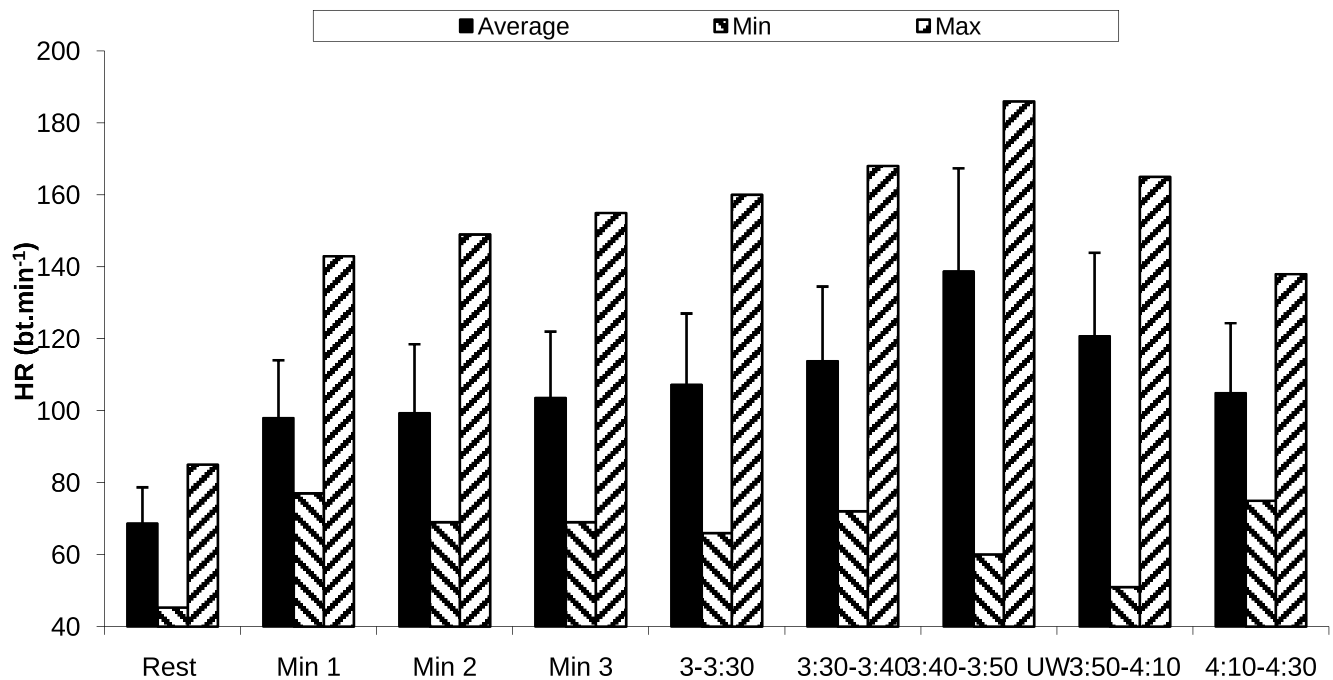

Figure 1. Average (*SD*), min and max heart rates of naïve subjects during their first helicopter underwater escape training run. *NB* Average resting heart rate = 68.6 $bt.min^{-1}$ (*n*=26)

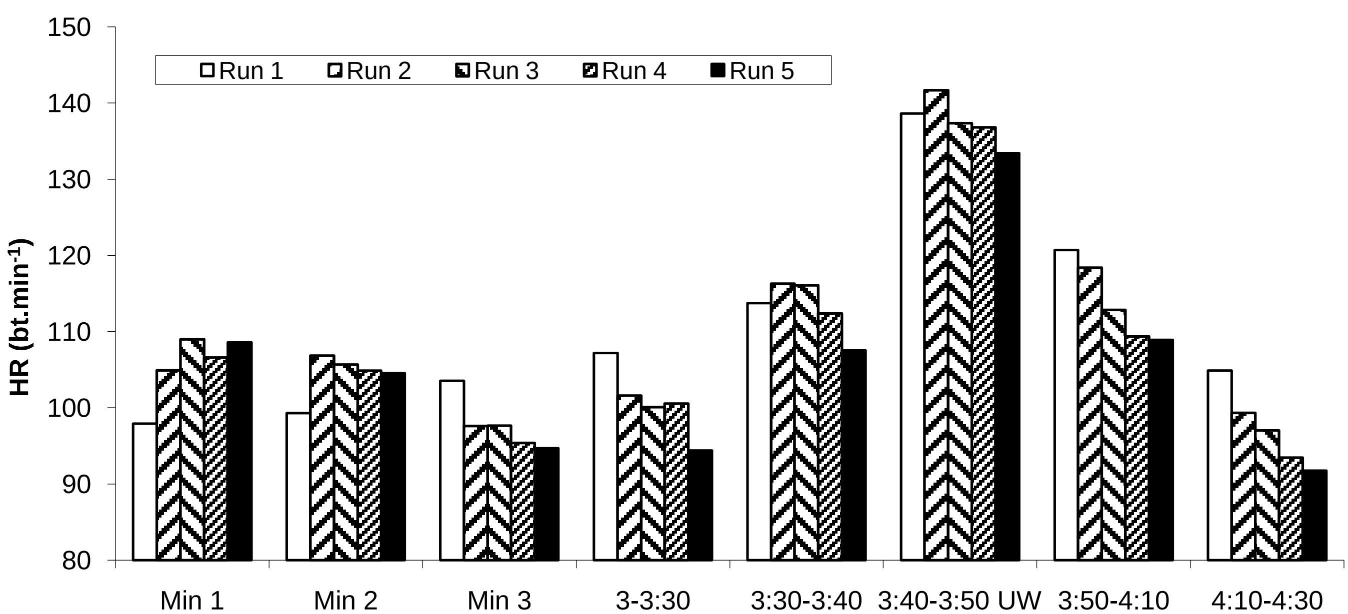

Figure 2. Heart rate response to helicopter underwater escape training. Naive subjects (Average data, *n*=26, X axis is in minutes. *NB* Average resting heart rate = 68.6 $bt.min^{-1}$)

Of the 130 immersions undertaken by the participants (*n*=26), 124 ECG traces were legible and 32 cardiac arrhythmias were identified (26%) in 21 different participants; only 6 of the arrhythmias occurred before submersion. The most prevalent arrhythmias observed were bradycardia, premature junctional escape, ventricular ectopics and broad QRS with Bundle branch block.

CONCLUSIONS

As evidenced by the heart rate response of the participants in the present study, HUET represents a significant stimulus to the sympathetic nervous system for some individuals, although there is a large degree of variability between individuals (Figure 1).

Cardiac arrhythmias can increase the risk of syncope and therefore drowning during submersion (Sharp, 2003), and electrical disturbances of the heart, which are undetectable at post-mortem, may be the cause of some immersion deaths that are either unexplained or ascribed to drowning. Current guidelines (Task Force 7, 2005) recommend that athletes demonstrating supraventricular premature beats should be investigated with a 12-lead ECG. Those demonstrating ventricular premature complexes are advised to have an exercise test and ECG.

The concurrent stimulation of the SNS (stress, activity and cooling) and PNS (breath holding, face immersion), and the release of the PNS stimulus with surfacing and the break of breath holding, can result in ECG abnormalities. The mechanism may involve a failure of the QT interval to match the diastolic interval during face immersion (Wong *et al*, 2009). The timing of the arrhythmias in the present study (normally after the release of breath holding) is consistent with earlier findings (Tipton *et al*, 1994). Hansel et al (2009) have also recently reported a high incidence of cardiac arrhythmias (supraventricular and ventricular premature complexes, right bundle branch block) in 12/16 (77%) subjects undertaking static maximal breath holds; the arrhythmias were related to breath-hold duration. Subjects with atrial premature complexes (n = 9) had a reduced body mass index ($P = 0.016$) and a higher decline in terminal SaO_2 ($P = 0.01$).

The anxiety-induced heart rate response close to the time of submersion was reduced after just one HUET run. Following submersion, the anxiety + activity driven heart rate response habituated within 4 runs, showing little change between runs 4 and 5. This suggests that a minimum of 4 HUET runs are sufficient to produce habituation to this exercise. The permanence of this habituation remains to be determined; the acquisition of this knowledge would have some implications for the duration between bouts of refresher training.

The ECG abnormalities observed in the present study were asymptomatic and probably of little clinical significance especially in the young (under 40 years), fit participants tested in the present study. They are common in athletes and usually not considered of clinical significance (Mounsey & Ferguson, 2003). It remains to be seen if this is the case with an older, less fit cohort of people, particularly if they find themselves in a situation requiring longer breath hold times and involving cold water, *i.e.* a real ditching.

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