

HUMAN INITIAL RESPONSES TO IMMERSION IN COLD WATER EFFECT OF WATER TEMPERATURE AND PRIOR HYPERVENTILATION

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INTRODUCTION

The initial responses to immersion in cold water include an "inspiratory gasp," hyperventilation, tachycardia, peripheral vasoconstriction and hypertension^{1,2,3}. These responses represent a significant threat to individuals who are immersed in cold water by choice or as a result of an accident. For individuals with pre-existing hypertension or coronary heart disease the cardiovascular responses may be particularly hazardous. For healthy individuals it is the respiratory responses which represent the major threat by preventing the conscious control of breathing at a time when it is most needed.

It is likely that the initial responses to immersion in cold water are responsible for the majority of the 400-1000 open water immersion deaths which occur in the U.K. each year⁴. Despite the obvious importance of these responses they have received little detailed investigation: the relationship between water temperature and the responses is still, for example, a matter for debate⁵.

The aim of the present investigation was to examine the initial physiological responses of human subjects to immersion in water at three different temperatures, chosen to represent the range of U.K. mean coastal water temperatures. The influence of hyperventilation before immersion on the respiratory response observed during immersion was also examined, in an attempt to obtain some insight into the mechanisms which initiate and modify this response.

METHOD

The experimental protocol was approved by a local ethical committee prior to subject recruitment. Eight naked subjects performed head-out immersions of two minutes duration into stirred water at 5, 10 and 15°C, and into 10°C after one minute of voluntary hyperventilation during which the end-tidal concentration of carbon dioxide was lowered to 3%. A repeated measures Latin Square experimental design was employed in which the subjects were all exposed to each of the four conditions once, with at least a week left between successive immersions.

Following a 10 minute pre-immersion period in thermoneutral air the subjects were immersed at 0.18 m.s⁻¹ into the cold water. During each experiment respiratory (respiratory frequency, tidal volume, expiratory/inspiratory volume and oxygen consumption), cardiac (heart rate) and thermal (chest skin temperature) responses were recorded. A week after their last immersion the maximum breath-hold time of subjects was determined at rest in air. The data obtained were examined using an analysis of variance technique and Sheffes method of multiple comparisons.

RESULTS

The chest skin temperature of subjects fell at a fast rate and was lower on immersion in water at 5 compared to 10°C ($P < 0.05$), and on immersion in 10 compared to 15°C ($P < 0.05$). Despite this, analysis of the respiratory and cardiac data collected during consecutive 10 s periods showed that differences between the variables recorded on immersion in water at 5 and 10°C were due to the duration of the responses evoked, rather than their magnitude during the first 20 seconds. The exception to this was the tidal volume of subjects which was higher on immersion in water at 15°C than 5 or 10°C.

Hyperventilation before immersion in water at 10°C did not attenuate the respiratory responses seen on immersion and the minute ventilations of subjects during the first and second minutes of immersion were significantly ($P < 0.01$) negatively correlated with maximum breath-hold time in air.

CONCLUSIONS

The results suggest that the respiratory drive evoked during the first seconds of immersion is more closely reflected in the rate rather than the depth of breathing at this time. It is therefore concluded that during the first critical seconds of immersion, water at a temperature of 10°C can represent as great a threat as water at 5°C and, in water at 10°C, the respiratory component of this threat is not influenced by the biochemical alterations associated with prior hyperventilation.

The inverse relationship identified between the maximum breath-hold time of subjects in air and their ventilatory response to immersion may be due to the differing capacities of subjects to consciously suppress ventilatory drive, from whatever stimulus: mechanical, chemical or thermal. This implies a conscious component in the habituation of the respiratory responses to immersion and has implications for the selection and training of those at high risk of immersion in cold water.

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