PERMANENCE OF THE HABITUATION OF THE "COLD SHOCK" RESPONSE

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INTRODUCTION

Sudden stimulation of the peripheral cutaneous cold receptors on immersion in cold water initiates the hazardous physiological responses collectively known as the "cold shock" response. This comprises a reflex inspiratory gasp, followed by a short period of uncontrollable hyperventilation and tachycardia. The reduction in breath hold time and voluntary control over breathing during this time increases the chances of aspirating water and thus drowning. For individuals with underlying heart or circulatory pathology, the increased cardiac workload associated with the tachycardia and cold-induced vasoconstriction may result in cardiac failure.

It is known that an adaptation to immersion in cold water can be developed following repeated exposures (1). The mechanism of this adaptation is, as yet, unclear but it appears to take the form of an habituation of central processes (2). The present study was designed to investigate whether the alterations that produce this habitation remain after a period of seven months.

METHODS

The experimental protocol was approved by a local ethics committee. Twelve healthy male volunteers aged 18 to 32 years participated in the experiment after giving informed written consent. The subjects were divided into 2 groups, a control (C) group (n = 4) and an habituation (H) group (n = **8).** Each subject undertook two 3-min, head-out immersions in stirred water at 10°C wearing swimming trunks. These immersions took place at the same time of day with 4 days separating the 2 immersions. In the intervening period, the C group were not exposed to cold water, but the H group undertook another **six** 3-min, head-out immersions in water at 15°C. Two months (December), **4** months (February) and 7 months (May) after their first immersion each subject undertook another 3-min, head-out immersion in water at 10°C.

Inspiratory minute volume (V_I), respiratory frequency (f_R), tidal volume (V_T) and heart rate (f_H) were measured during each immersion and recorded continuously.

RESULTS

All of the subjects in group C, but only 5 of the subjects in group H were able to complete all 5 immersions in 10°C. One subject missed the immersions at months 2 and 4, and 3 subjects missed the immersion at month 7. Missing data were estimated using the Genstat routine, thus keeping the subject numbers constant for each immersion. Mean data for both groups are presented in Tables 1 and 2.

Table 1. Mean values for both groups obtained during first 30 s of immersions in water at 10°C for f_R (breath·min^{-1}), V_I (L·min^{-1}) and f_H (beat·min^{-1}).

	Group	day 1	day 5	month2	month4	month7
f_R	H	47.3	24.0	34.4	33.9	32.1
	C	37.0	37.5	38.0	35.5	31.0
V_I	H	72.2	31.3	58.5	55.6	49.0
	C	64.8	70.9	82.8	77.0	68.4
f_H	H	128.0	108.5	111.5	108.1	90.2
	C	116.4	115.0	106.6	106.0	97.5

Group H showed a significant reduction in f_R over the first 30 s of immersion at day 5 (immediately after the habituation regime; $P < 0.05$), over subsequent immersions f_R increased but not significantly (Figure 1). Over the same time period, group C showed no alteration in f_R across immersions. In the remaining 150 s of immersion, the H group showed a reduction at day 5 ($P < 0.05$) and thereafter a gradual increase over time, while the C group showed no significant changes across the immersions.

Table 2. Mean values for both groups obtained between 30 and 180 s of immersions in water at 10°C for f_R (breath·min^{-1}), V_I (L·min^{-1}) and f_H (beat·min^{-1}).

	Group	day 1	day 5	month2	month4	month7
f_R	H	32.3	17.5	22.0	21.7	21.4
	C	28.8	26.5	29.0	22.8	18.8
V_I	H	56.8	17.5	29.4	28.6	25.1
	C	58.8	47.3	65.2	35.5	30.2
f_H	H	116.4	89.8	89.9	93.6	77.2
	C	104.3	88.8	95.5	83.8	75.3

A similar response was seen with V_I, the H group showing a significant decrease in the first 30 s of immersion at day 5 ($P < 0.05$), thereafter V_I increased with time. The C group showed no change in the V_I response. During the last 150 s of immersion, the V_I response of the H group was attenuated at day 5 ($P < 0.05$) and showed a tendency to increase on subsequent immersions. The C group

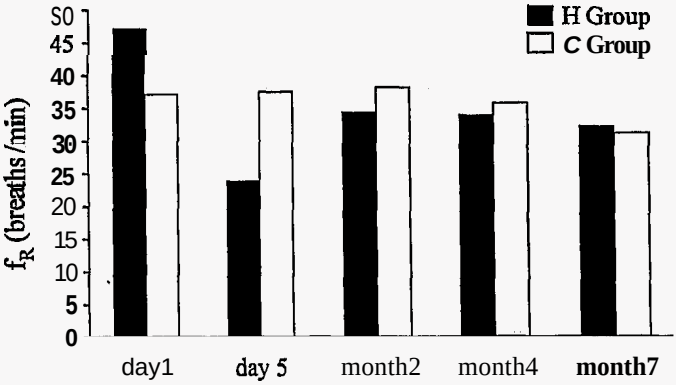

Figure 1. Mean respiratory frequency for both groups during the first **30** s of immersions in water at 10°C.

showed a reduction in V_I between months **2** and 4 ($P < 0.05$) over the remaining **150 s** of immersion. No significant differences were observed in either group across immersions with regard to V_T during the first **30** s.

In the first **30** s of immersion, the C group showed no change in their f_H response, whereas the H group showed a gradual decline with repeated immersions; this reached significance between days 1 and **5** and months 4 and **7** ($P < 0.05$). Over the last **150 s** of immersion, f_H was attenuated in both groups between day **1** and **5** ($P < 0.05$) and remained unchanged on subsequent immersions.

DISCUSSION

We have previously reported that repeated immersion in water at **15°C** reduces the responses to immersion in water at 10°C **(3).** This study has focused on the permanence of the alterations which produce the habituation to the cold shock response. f_R is thought to be a better indicator of respiratory drive than either V_I or V_T under conditions similar to those of the present investigation (4). The H group showed the largest reduction in this response at day **5,** at the end of the habituation regime. At month **2** the response was still reduced compared to the first immersion but was greater than that observed at day **5** (approximately half the habituation was lost). Over the remaining months, the average responses of the H group remained fairly constant. This demonstrates that part of the habituation developed was short-term and reversible in nature and disappeared over the first **2** months, while another component of the habituation included more permanent changes.

The responses of the C group to immersion in cold water remained the same between day 1 and day **5** and over the months examined (February, May, October and December) showing no tendency towards seasonal variation in the magnitude of the response evoked.

There appeared to be considerable individual variation in the ability to acquire and maintain an habituation to the cold shock response. Given the small

number of subjects who participated in the present study, any conclusions must be regarded with caution. With this in mind, the results indicate that once an habituation has been produced, the attenuation of the responses can last up to 7 months. To maintain at least a proportion of the habituation, it may be necessary to undertake periodic cold exposures; the present findings suggest that, at worst, these should occur every 2 months. The results from the C group indicate that seasonal variation in the responses to cold water immersion is unlikely in unhabituated individuals.

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