THE EFFECT OF REPEATED SHOWERING ON THE INITIAL RESPONSES TO COLD WATER IMMERSION

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INTRODUCTION

Immersion in cold water initiates the hazardous physiological responses collectively known as the "cold shock response." These comprise a reflex inspiratory gasp, tachycardia and uncontrollable hyperventilation, which are initiated by stimulation of peripheral cold receptors. Following repeated immersions, these responses are reduced by habituation.

The habituation process is not strictly temperature dependent and occurs through alterations in central pathways rather than the cutaneous receptors (1,2). The cold shock response can also be initiated by cold showers (3). However, it is not known whether repeated cold showers reduce the responses to whole-body cold immersion. The aim of this study was to investigate showering as a method of inducing habituation to the initial responses to cold water immersion and to determine the importance of the rate of change of skin temperature ($\dot{T}_{sk}$) for the habituation process.

MATERIALS AND METHODS

The experimental protocol was approved by local ethics committees. Twenty-four healthy volunteers (18 males, 6 females; age 26.9 ± 5.6 years; height 176 ± 9 cm; mass 78.9 ± 11.1 kg) participated in the study after giving informed written consent. The subjects, who were unacclimatized to cold, undertook two 3-min head-out, seated immersions in stirred water at 10°C wearing swim wear. The immersions occurred at the same time of day and were separated by 4 days during which time the subjects took 6 cold showers. The subjects were randomly split into 4 groups with different showering regimes: 3 min at 10°C on the back (10B); 3 min at 15°C on the back (15B); 30 s at 10°C on the back followed by 30 s on the front (10BF); and 35°C reducing to 10°C over 40 s followed by 3 min at 10°C on the back (H10). The angle of the shower was adjusted for each subject so that the head was not wetted, and the flow rate was kept constant at 5 L·min^{-1}. Previous studies (1,2) have established that the initial responses to cold water immersion are not altered when the immersions are separated by 4 days.

Inspiratory minute volume (V_I), respiratory frequency (f_R) and heart rate (f_H) were recorded continuously. Skin temperature (T_{sk}) was measured on the chest, upper back, forearm, thigh and calf. Surface area of the **skin** (SA) cooled by showering was estimated by infrared thermography.

RESULTS

On immersion, ($\dot{T}_{sk}$) averaged 0.36 ± 0.05°C·s^{-1} in the first 30 s (time zero taken from when the feet were immersed). During the first 30 s of showering, on the back for each condition was as follows: 10B 0.59 ± **0.01°C·s^{-1}; 15B 0.46 ± 0.05°C·s^{-1}; H10** 0.60 ± **0.05°C·s^{-1}** and 10BF ***0.58*** ± **0.02°C·s^{-1}**. It was expected that H10 would show a slower than 10B. This was probably masked by the initial increase in T_{sk} in H10 and the response of the covered thermistor. The ther-

Table 1. The initial responses (1,2) during the fist and last immersion (I1 and I2) and shower (S1 and S6) for groups 10B, 15B, H10 and 10BF, respectively.

10B	Time (s)	I1	I2	S1	S6
f_R	0-30	54 ± 14	44 ± 16**	29 ± 8	18 ± 6*
	30 - 180	35 ± 13	31 ± 12	22 ± 7	17 ± 3*
V_I	0-30	84.6i23.4	77.5f26.7	51.9f17.9	28.8 ± 16.9*
	30-180	60.6i15.2	45.7f22.3	38.0f13.9	17.3 ± 5.5**
f_H	0-30	120 ± 18	120 ± 18	98 ± 16	78 ± 12**
	30 - 180	115 ± 16	104 ± 22	100f20	79 ± 13*
15B					
f_R	0-30	43 ± 15	44 ± 28	20 ± 6	16 ± 5
	30 - 180	32 ± 19	33 ± 23	18 ± 6	**16 ± 6**
V_I	0-30	74.9f14.5	75.5 ± 20.6	34.8 ± 12.6	15.9 ± 4.1**
	30-180	49.0i18.1	37.1 ± 16.9**	21.5 ± 9.7	13.3 ± 2.0**
f_H	0 - 30	136 ± 7	132 ± 20	95 ± 26	78 ± 12*
	30 - 180	119123	105 ± 25**	83 ± 18	76 ± 10
H10					
f_R	0-30	37 ± 17	**30** ± 16**	24 ± 8	21 ± 8
	30 - 220	22 ± 8	20 ± 10	16 ± 5	13 ± 4**
V_I	0-30	58.3f21.4	57.4i19.6	33.3f18.1	22.0 ± 9.4*
	30-220	30.5i15.2	26.5 ± 11.9	28.0 ± 21.6	17.7f8.9
f_H	0-30	100 ± 14	110 ± 16	91 ± 10	85 ± 12
	30-220	87 ± 15	95 ± 23	87 ± 23	80 ± 14
10BF					
f_R	**0-30**	33 ± 8	26 ± 10*	20 ± 7	18 ± 4
	30 - 60	22 ± 5	19 ± 6	20 ± 6	18 ± 3
V_I	0-30	**58.8i20.8**	54.1i24.3	42.8f13.0	**26.2 ± 6.6****
	30-60	43.1 ± 15.5	30.1 ± 13.8*	38.1 ± 7.1	28.4 ± 9.9
f_H	0-30	106 ± 24	114 ± 28	98 ± 19	85 ± 20*
	30-60	102 ± 22	94 ± 23	96 ± 19	82 ± 18*

'Values represent the mean ± SD (n = 6) from 0 to 30 s and 30 to the end of the shower/immersion.

Units of measure: f_R (breaths·min^{-1}), V_I (L·min^{-1}) and f_H (beats·min^{-1}).

* P<0.05, ** P<0.01, I1 vs. I2 and S1 vs. **S6.** Wilcoxon signed ranks **test**

mographs taken at the end of the showers showed that in groups 10B, 15B and H10, 23% of **SA** was cooled, with the vast majority of this being on the back. In group 10BF, the **SA** cooled was approximately **34%.**

The mean resting f_R, $\dot{V}_I$, and f_H values for all subjects were 14 ± **4** breaths·min^{-1}; 12.7 ± **3.4** L·min^{-1} and **80** ± 14 beats·min^{-1}, respectively. The cardiac and respiratory responses to the first and **last** immersions (I1 and I2) and showers (S1 and S6) for each group and the levels of significance are given in Table 1. Following repeated exposures, the respiratory responses during the last shower were found to be attenuated. f_H was also reduced in all groups except H10. Compared with the first immersion, f_R over the first **30** s of the second immersion was reduced by approximately **20%** in groups 10B, H10 and 10BF. The tachycardia induced on immersion in water at 10°C was not reduced by repeated showers except in group 15B and then only over the last 150 s.

DISCUSSION

The 20% reduction in f_R seen over the first 30 s during I2 compared with I1 in the current study (groups 10B, H10 and 10BF) contrasts with a **41%** reduction in f_R observed during previous studies in the first **30 s** of a 10°C immersion following repeated immersions in water at 15°C (1) and the 19% reduction in the f_R response over the first **30 s** of 10°C immersion of the right side of the body following repeated 10°C immersions of the left side of the body (2). This suggests that repeated showering is not as effective as repeated head-out immersions in producing a habituation to the cold shock response, but the relatively large habituation seen for **SA** exposed with showering suggests that the torso **was** particularly sensitive. This is supported by previous studies **(4).**

Between-group comparisons in the present study can only give an indication of the mechanisms involved in the habituation process owing to the small number of subjects in each group. With *this* in mind, 15B were the only group that did not show a reduction in f_R during I2. This group also showed the slowest $\dot{T}_{sk}$ and the highest absolute $\dot{T}_{sk}$ during their showers. Previous studies have demonstrated that repeated head-out immersions in water at 15°C ($\dot{T}_{sk}$ = 0.33°C·s^{-1}) reduced the responses to immersion in water at 10°C(1). Thus, exposing 90% of the **SA** @cad-out immersion) to a $\dot{T}_{sk}$ of **0.33°C·s^{-1}** will produce an habitnation to the cold shock response on immersion in 10°C, but exposing **23%** of the **SA** to a $\dot{T}_{sk}$ of **0.46°C·s^{-1}** will not. **As** the areas cooled by the 15°C water had the same absolute temperature at the end of the shower or immersion, the difference in the habituation produced must be due to the **SA** exposed.

When the results of group 15B are compared with those of groups 10B and H10, which had the same **SA** exposed to cold, the $\dot{T}_{sk}$ appears to determine the level of habituation produced; 10B and H10 showed a reduction in f_R on I2 but 15B did not. This is supported by the findings of Mekjavic et al. **(5)** who reported that the respiratory drive during sudden cold water immersion was closely correlated with $\dot{T}_{sk}$. However, it should be noted that the absolute T_{sk} was lower in groups 10B and H10 compared with group 15B, and this may have influenced the results.

The present study has provided evidence that there is both a spatial (SA) and probably a temporal ($\dot{T}_{sk}$) summation of the cold stimulus to produce a habituation of the cold shock response. The threshold for producing the habituation appears to be influenced by the SA exposed The smaller the SA cooled, the faster the $\dot{T}_{sk}$ required and vice-versa.

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